IMPULS Lesson Study Immersion Program *2016* Overview Report

March 2017

“IMPULS Lesson Study Immersion Program 2016
Overview Report”
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1 Preface

Project IMPLUS is a newly established project funded by the Ministry of Education, Culture, Sports, Science & Technology of Japan since 2011. The Project is housed in the Mathematics Education Department of Tokyo Gakugei University, Tokyo, Japan. The director of the project is Professor Toshiakira FUJII, and the project members include all the faculty members of the mathematics education department—Professors Shinya OHTA, Koichi NAKAMURA, Keiichi NISHIMURA and Tatsuhiko SEINO. Dr. Akihiko TAKAHASHI of DePaul University joined the project as a specially appointed professor. Ms. Naoko MATSUDA also joined the project as a project staff member. The purpose of the project is two-fold. First, as an international center of Lesson Study in mathematics, Tokyo Gakugei University and its network of laboratory schools will help teacher professionals from throughout the region learn about lesson study and will thereby prepare them to create lesson study systems in their own countries for long-term, independent educational improvement in mathematics teaching. Second, the project will conduct several research projects examining the mechanism of Japanese lesson study in order to maximize its impact on the schools in Japan. Under these main purpose, we are working for ;

1) ***Research*** on Japanese Lesson Study to come up with ideas for establishing innovative teacher education systems for long-term, independent educational improvement in teaching mathematics.
2) ***Professional development*** to disseminate ideas for establishing innovative teacher education systems for long-term, independent educational improvement in mathematics teaching. Workshops and institutes would examine how to implement ideas for Lesson Study and innovative ideas for professional development in various schools with different systems and cultural back ground in order to prepare them to create in their own countries' systems for long-term, independent educational improvement in teaching mathematics.
3) Facilitate opportunities for researchers, administrators, and practicing school professionals throughout the region to ***exchange their ideas*** to improve their education systems for teaching mathematics.

The IMPULS lesson study immersion program was designed to give mathematics education researchers and practitioners from outside Japan an opportunity to examine authentic Japanese Lesson Study in mathematics classrooms. The major purpose of this program is for us to receive feedback on the strengths and weaknesses of Japanese Lesson Study and to discuss how to improve mathematics teacher professional development programs. To accomplish this, we invited leaders of mathematics education to immerse themselves in authentic Japanese lesson study, especially school-based lesson study, and to observe mathematics research lessons in elementary and lower secondary grades.

The program started since 2012 and this year's program was held in Tokyo and Yamanashi in Japan from June 20, 2016 to June 27, 2016. In total 33 mathematics educators (12 form U.S., 11 from U.K., 3 from Australia, 2 from Netherlands, 2 from Portugal, 1 from Malaysia, 1 form

Singapore and 1 from Switzerland) including mathematics education professors and so on participated in. For this year, IMPULS invited one of IMPULS overseas support committee, Dr. Tad Watanabe, Professor of Mathematics Education at Kennesaw State University, to facilitate discussion among participants and interpret lesson plans, lesson itself and post lesson discussions. All lesson plans were translated by Dr. Tad Watanabe and distributed before observation. And one external evaluator, Dr. Lee Kim Eng, Christine, Associate Professor, Curriculum, Teaching and Learning (CTL), National Institute of Education, Singapore, gave us useful feedback with objective evaluation of program.

We would like to take this opportunity to thank all of our overseas support and evaluation committee, cooperative schools which kindly welcomed our visiting and all concerned professionals for their hard work.

2 Contents of Program

This program is designed for deeper understanding of Japanese lesson study and it consist of these contents below.

1) Basic lecture on Japanese mathematics lesson and lesson study (1 day)
2) Observation of research lesson and post lesson discussion (7 lessons)
3) Discussion among participants, Q/A and review session

Detailed schedule is shown as below.

Date	Time	Contents
June 20	AM	Opening Session, Workshop: Mathematics teaching and learning in Japan,Lesson Study in Japan,Teaching through problem solving and Kyouzai-Kenkyu
	PM	Workshop: Japanese mathematics lessons and lesson study
June 21	AM	Preparation for the research lesson observation
	PM	<Research Lesson &PLD1> Sugekari Elementary School (Schol-based LS, Grade6)
June 22	AM	Preparation for the research lesson observation
	PM	<Research Lesson &PLD2> Saiwai Elementary School (School-based LS, Grade 4)
June 23	AM	< Research Lesson 3> TGU International Secondary School (Grade 7)
	PM	< Research Lesson &PLD4> TGU International Secondary School (Specially Appointed LS, Grade 9)
June 24	AM	Visit Ryuo Elementary School in Yamanashi
	PM	< Research Lesson &PLD5> Ryuo Elementary School (School-based LS, Grade5)
June 25	AM	< Research Lesson 6> University of Yamanashi Attached Elementary School (Cross-district LS, Grade1)
		< Research Lesson 7> University of Yamanashi Attached Elementary School (Cross-district LS, Grade 6)
		Post lesson discussions
June 26		Free
June 27	AM	Discussion to wrap up the Lesson Study Immersion Program
	PM	Closing session

June 21: Sugekari Elementary School

Group report by:

Bob Sawyer**,** David Wylde**,** DerekRobinson**,** David Freeman**,** Paul Rowlandson**,** Kari Laux

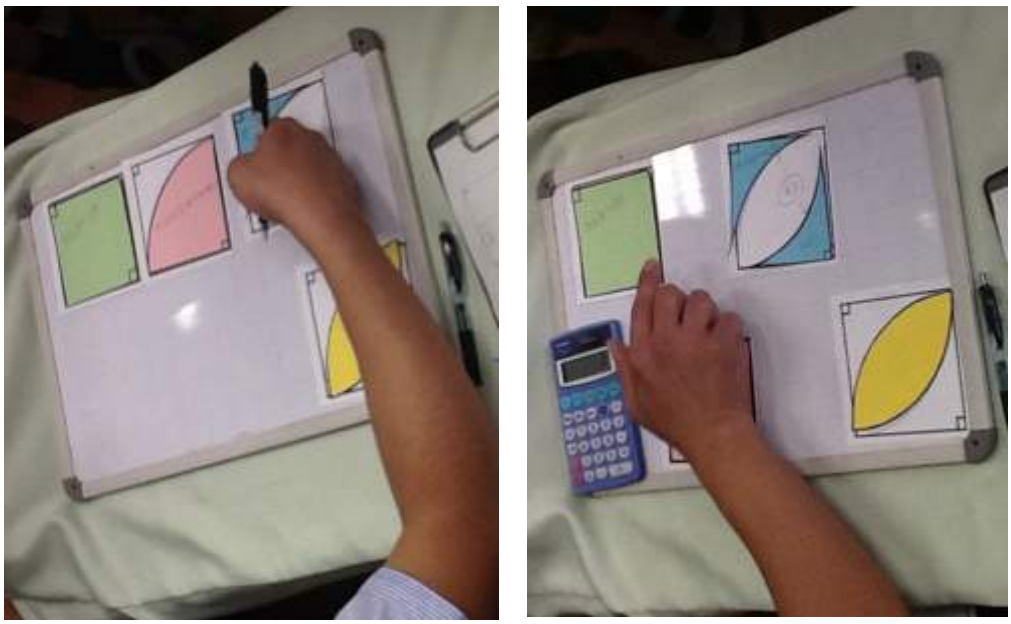
What are the primary lesson goals?

- Students will be able to calculate the area of figures.
- Students will be able to approximate figures in their surroundings and determine their area.

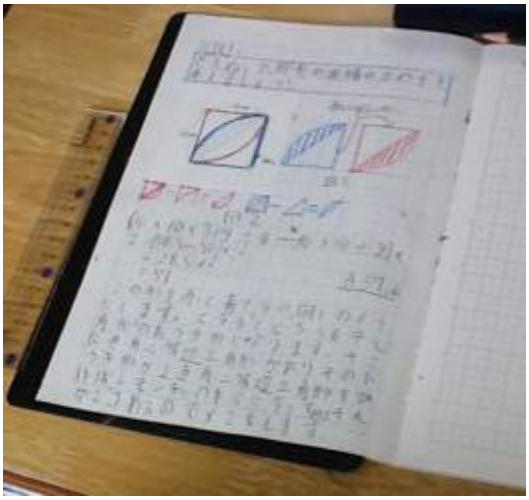
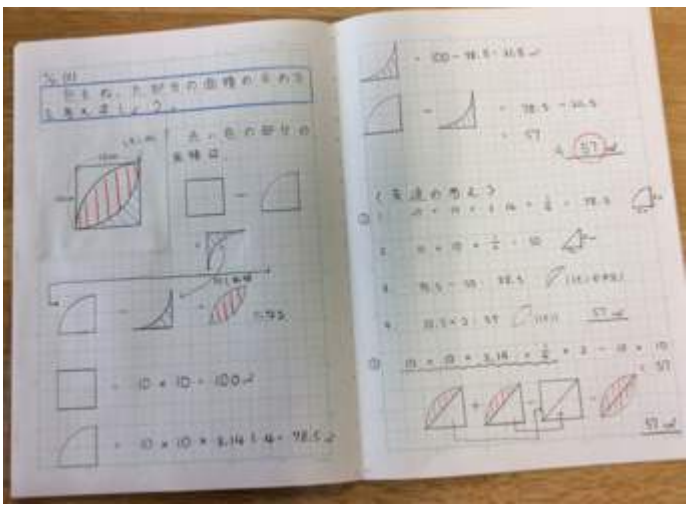
Where is the lesson located within the unit (in relation to previously studied topics and ideas to be studied in the future)?

Students have covered how to calculate the area of a circle through investigation. They are able to calculate the area of a circle using the formula and have looked at how doubling radius effects the area. In the most recent lesson they were calculating the area of semi-circles.
After this lesson they will be moving onto calculating the area of sectors.

Start &End Time	Lesson Phase	Notes
	1. Introduction, Posing Task	**-Strategies to build interest or connect to prior knowledge** -Exact posing of problem, including visuals • Recap area of circle and semi-circle using the mystery box. • Mystery box created a sense of intrigue • After the reveal of the circle and semi-circle students assumed the next shape was quarter circle, this was not the case, but it encouraged students to start thinking about this shape. This was then picked up in the main activity. Perhaps this helped the students to see the quarter circle within the 'lemon shape' because they have already imagined it in that space. • When the shape was revealed, the teacher asked them to name shape and what shapes do you see. The students named the shape 'Lemon'. This was different to what the teacher had anticipated (Leaf) He also added "Let's think about ways of calculating the shaded area" A student was then selected to read the question.  *Mr Nakayama using the mystery box to engage students in the problem* • Introduction met the first point of observation which was to capture the students' imagination and motivated them to engage in the task. All of the above was done with pace, it was completed in less than 5 minutes.

	2. **Independent Problem-Solving**	**-Individual, pairs, group, or combination of strategies?** -Experience of diverse learners - Teacher's activities • We feel students were given insufficient working time on the problem before support was offered. If the students are used to this very short thinking time it might mean they know they do not have to think about the problem as eventually the solution will be presented for them through the board work. • Ten students went to the front to receive extra support. This intervention resulted in only 5 of the students using the same strategy. The intervention used thought provoking questions. As each student began to understand the problem, they slowly moved away to work independently.  *Mr Nakayama guiding students through the problem at the 'Lab'* • Teacher activity – moving around the room making careful notes of the various strategies being used. • All 3 approaches identified in the lesson plan were used by the students in the lesson – this was surprising. • Some students finished very quickly, they then spent time writing their explanation. • Other students who had finished waited patiently

	3. Presentation of Students' Thinking, Class Discussion	**Student Thinking / Visuals / Peer Responses /Teacher Responses** Photos to document chronology (use new box for each new student idea presented] • Students presented their answers at the board. The teacher effectively utilised the responses of individual pupils by selecting those pupils he knew had been working on the particular strategy. He then used other students to develop a shared understanding of the strategy.  *Final board with all three approaches clearly seen* • For the next strategy he used the calculation rather than the physical model to start with and then built the physical representations of the answer. This strategy deepened their understanding and helped make links between the two. • The student who offered the calculation for solution one explained the solution this changed for the other two solutions, different students explained for the later solutions.  *Student matching the diagrammatic representation to the calculation* • The teacher was very patient when the students were giving and explaining their answers. • The nurturing of the learning by the teacher was very impressive, all operational commands were given in an affirmative supportive manner • Teacher blended in the use of ¼ being the same as dividing by 4 seamlessly during the discussion • Precise language used when describing the triangle – isosceles right angled triangle.

	4. Summary /Consolidation of Knowledge	Strategies to support consolidation, e.g., blackboard writing, class discussion, math journals. • Quality/clarity of their written recording was excellent.  *Example of a students work clearly showing their solution and final comments* • Verbal reasoning was raised as an area for improvement in the post lesson discussion. This was due to the lack of time given to the students to discuss. This might be a feature of the desire to get through the lesson plan rather than have the flexibility to ensure that at whatever stage the students get to their understanding is deep and complete. • Teacher summery question – "what kind of shapes did you use to solve the problem?" • Teacher commented that we found the area of an unknown shape using shapes we already know how to calculate the area. Teacher then asked to select your favorite solution from your friend. • There was insufficient time spent on this part of the lesson as the pupils really did not explain why they had chosen a different strategy from their friend and what was good or different about it.  *Example of a student's answer along with a different solution copied from another student*

What new insights did you gain about mathematics or pedagogy from the debriefing and group discussion of the lesson?

The link between mathematical modelling and physical images that are used to build collective understanding - very skillfully demonstrated in the lesson. In the UK we have a linear hierarchy of moving from 'concrete' to abstract. Maybe this is something we need to reconsider and develop students' abilities to 'create first in the mind'.

The balance between teacher speak and student speak – The teacher primarily led the discussion with student comments usually being directed back to the teacher. It would be interesting to know the level of understanding of those students that did not speak in the lesson. Furthermore, since the majority of the students will have the same notes as the teacher, how will an analysis of these notes enable the teacher to establish the level of understanding of the lesson?

Note taking should be about recording of pupils' own ideas, not the collective work.

How can we mirror the use of the board with the interactive boards in the U.K?

The objective of the lesson was achieved as stated in the lesson plan i.e. the summary of the learning was as stated. The question is whether this was accurate in terms of being a true reflection of the learning or whether the teacher was just able to achieve this as a result of the collective work on the board. .

What new insights did you gain about how administrators can support teachers to do lesson study?

The leadership of schools need to be committed to embedding the process into their professional development programs. The culture of 'teacher as researcher' needs to be embedded. In the UK, we do have the time to do this, but the challenge would be for heads to have the confidence to reduce the intensity of learning walks and lesson observations in order to create capacity elsewhere. This would require a shift in culture that has been developed in the UK through a rigorous and punitive accountability regime.

The Lesson Study approach used in Japan focuses on the deepening of subject knowledge and the nurturing of engagement in learning. In the UK we have been exposed to a range of teaching and learning strategies (AfL, 3 part lesson, CAME, diagnostic question, Space Teaching etc) all of which have systematically failed to embed a culture of teacher as learner and the development of their own craft.

The lesson study in the school is a whole school activity with an overarching aim. The research question has been thoughtfully developed in consideration of the whole school priority and is worked on for an extended period of time (two years is not unusual).

In addition to these points, as the UK is currently looking at ways to adopt a 'mastery' style to teaching and learning, and programs of learning and assessments are being reformed at every stage of education to introduce new content and make the curriculum more challenging, there is heightened attention for CPD that improves subject knowledge and improving ways at introducing content to students. This is in contrast to the more type of CPD that has previously popular in the UK focusing on teaching style (e.g. 3 part lesson etc).
Therefore, although the time is right to implement lesson study to UK schools and teachers, we anticipate that it could cause tensions.

How does this lesson contribute to our understanding of high-impact practices?

The detailed planning and importantly the consideration of anticipated student responses is a key feature of high impact practice. This process not only enables the teacher to manage the 'flow' of the lesson but also deepens the teacher's own subject knowledge and 'teaching craft'.

The development of an affirmative learning culture is also a key area of high impact practice. It is clear that over time students are nurtured to take responsibility for their own learning and as the students mature they increase their engagement in the lesson not necessarily by a direct contribution, but by listening carefully to the teacher and other and by detailed and effective note taking.

The culture of the 'productive struggle' is also an important feature. Students are asked to consider the problem on their own and only if they cannot get started do they ask for help. This builds up resilience and confidence in approaching new problems and mathematical situations.

June 22: Saiwai Elementary School

Group report by: Felicity Ames Stéphane Clivaz
Cristina Maria da Silva Morais Marisa Alexandra Ferreira Quaresma Hanna Sufrin

What are the primary lesson goals?

As stated in the Lesson Plan:
"Students can think about ways to calculate 48÷3 using diagrams and their prior knowledge of division." (p. 1) This primary goal includes the following elements:

- Students will think about ways to calculate 48÷3 such as decomposing the dividend, using concrete materials, diagrams and mathematical expressions.
- Students will be able to summarize how they used their prior learning to make these calculations.
- Students will express and record their ideas for calculating 48÷3 using pictures/diagrams that can be understood by others.
- Students will explain their ideas in ways that can be understood by others.
- Students will understand that division of 2 and 3 digit numbers by 1 and 2 digit numbers is based on basic division facts by exploring ways to calculate (unit goal).
- Many students will share ideas during the lesson.

Additionally, the school's Lesson Study Research Theme is: "Mathematics lessons in which students will autonomously reason and create" (with special value placed on questions and sharing).

Where is the lesson located within the unit (in relation to previously studied topics and ideas to be studied in the future)?

During the previous school year (Grade 3) students learned about the meaning of division and the concept of division as the inverse of single digit multiplication, as well as division with remainders. In particular, they explored 36÷3.

This lesson is part of the first unit on division in Grade 4, titled "Let's Think About Ways of Calculation," with a focus on the calculation of 48÷3. Students will continue their division learning in Grade 4 with units on 2 and 3 digit numbers divided by 1 digit and then 2 digit numbers. They will also learn more about the properties of multiplication and division.

<table>
<tr><th>Start &End Time</th><th>Lesson Phase</th><th>Notes</th></tr>
<tr><td>1:32 pm – 1:54 pm</td><td>1. Introduction
Posing Task</td><td>
Strategies to build interest or connect to prior knowledge
There are □ ice creams in each box. If 3 people share the ice creams fairly, how many ice creams will each person receive?
Student were standing (because of the beginning of the lesson). The teacher asked the students to read the problem by themselves and to sit when they had read and understood.
Teacher added: It’s ok if you do not understand, it’s good if you know you didn’t understand.

The lesson was then a dialogue between the teacher and the students. The following points were raised:
<table>
<tr><th>Teacher</th><th>Student</th></tr>
<tr><td>What numbers can we put in the box if we want to share equally?</td><td>3; 6; 9
A student says: 2</td></tr>
<tr><td>What does equally mean, is it important?</td><td>Yes it is.
It means that everybody is happy
(teachers draws 3 happy faces)</td></tr>
<tr><td>So, would 2 be adequate?</td><td>No</td></tr>
<tr><td>What kind of operation?</td><td>Division</td></tr>
<tr><td>How many are sharing?</td><td>3</td></tr>
<tr><td>How many would each person get?</td><td>We don’t know yet</td></tr>
</table>
</td></tr>
<tr><td></td><td></td><td>
The teacher ask students to stand up, talk with their neighbour about which numbers can be put in the box and to sit down when they are done.
<table>
<tr><td>Which numbers in the box?</td><td>3; 6; 9; 12</td></tr>
<tr><td>I will use the 12
(Teacher writes 12 in the box).</td><td></td></tr>
</table>
Students read the problem aloud chorally.
Teacher ask students to write down the math expression and the operation they
</td></tr>
</table>

Raise your hands if you think the answer will be greater than 10.	Many hands
Can we get closer?	Shout out numbers and math facts, i.e. 3x10, 3x11, 3x12

have used, and then to talk with their neighbour.

What operation did you write?	12÷3
How do you solve it?	With 3s facts

Teacher says: It's too easy, I underestimated you! I'll give you a more challenging one.

He puts 4 rectangular papers on the board and says: now we have 12 ice cream in each of these boxes. How many are there? 12; 24; 36; 48.

Teacher says: I am going to write down the problem. He writes on the blackboard: "There are 12 ice creams in each box, and there are 4 boxes. If 3 people share the ice creams equally..."

He stops, insists on "equally", and makes students guess what will be the end of the problem and the students say: "How many ice creams will each person receive?"

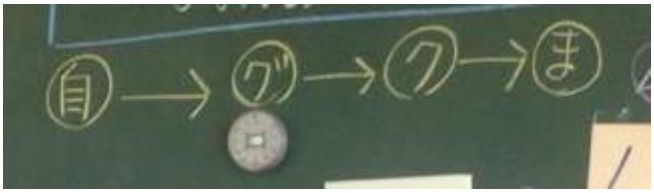
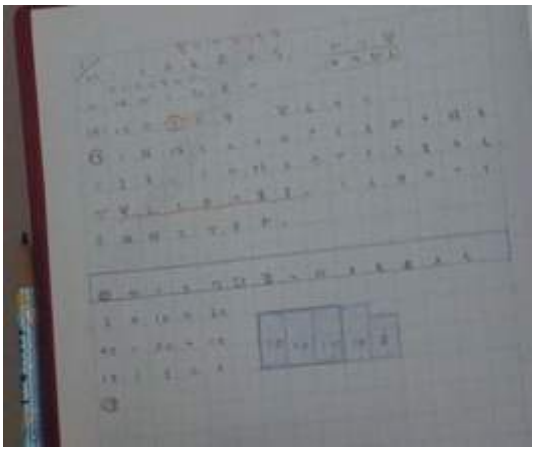
The teacher writes it, asks the students to write it in their journals too, and to check with their neighbors that it's written correctly.

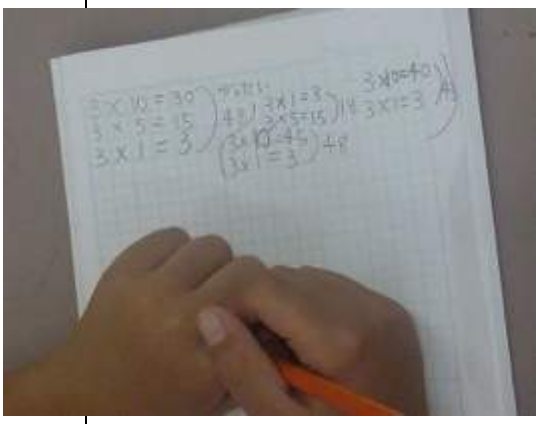
How many ice creams?	48
What is our expression?	48÷3
Can you solve this? I don't think you can.	Yes we can! We have done this!

At this point the teacher guides the students in an exchange focused on estimation:

Finally, the teacher gives these directions prior to kicking off the independent problem solving portion of the lesson:

- Think about HOW to get the answer, not just the final number.
- The goal is to find ways of calculating 48÷3.
-

1:54 pm – 2:04 pm	2. Independent Problem-Solving	**Individual, pairs, group, or combination of strategies?** The teacher shows the structure of the rest of the lesson:   (Independent solving – group discussion – whole class discussion – summarize) Students start to solve the problem individually and the teacher moves around the classroom. Suddenly, the teacher asks for students' attention and says that a student asked about long division. Then, the teacher says to the whole class: "We will talk about it later". At this moment, one student (S01) that had written "48÷3=" wiped out this mathematical expression. The teacher asks the students who were struggling with the task to quickly "spy" on their peers' work to get ideas (named in the lesson plan as 'spying time'). The students who chose to stand up walked around the room and saw what their peers were doing. Students used different strategies to solve the problem: Perhaps because the students previously had discussed if the result would be higher or lower than 10, this student started by calculating 3x10=30. After that, the student found the difference between this and 48 (18). Finally, he tried to relate 18 to the 3's facts (probably he thought about 6x3=18). It isn't clear if the student used this as a tool to think about 48÷3 or just to represent the problem.   Starting with 3x15, probably because this student already knew this fact, he continued to do the 3's fact table until 3x18. It is unclear why the student didn't stop at 3x16.



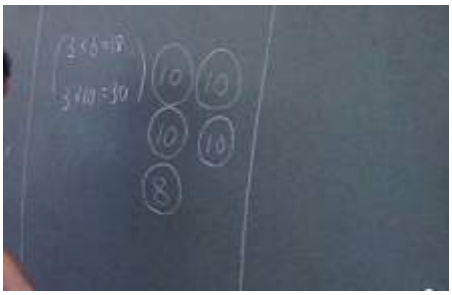
At first, the student seem to have obtained 48 using 3's facts (3x10+3x5+3x1). After this, the student seemed to try other combinations of 3's facts, but appeared to always repeat the same facts and make errors.

The student started by drawing 48 circles and did groups of 3. By counting the number of groups the student would obtain the answer to 48÷3

The student seemed to first decompose 48 in 40+8, then he also split 40 into 30+10 and tried to solve 30÷3, 10÷3 and 8÷3. He was able to calculate the first one, calculated the quotient and the remainder for the second one and gave an incorrect answer for the third one (he seemed to have thought about 8÷3 as 6+2). Then, he seem to add all the quotients and remainders to find his answer. It becomes clear that the student struggled with the 3's facts and with the meaning of the remainders.

Teacher announces the individual problem solving time is over and asks, “Who has rock?’ (rock means the student did not have difficulty with the problem). Some students showed the rock symbol. The teacher then does the same for scissors (students that are still figuring out the solution to the problem) and paper (students who are still unsure of how to solve the problem). The students then formed small groups with each group having at least one student who had understood and solved the problem (shown the ‘rock’ symbol).
The teacher asked for those who understood the problem to explain their ideas within the group. The students who were still working through the problem or who still did not understand the problem should try to understand.

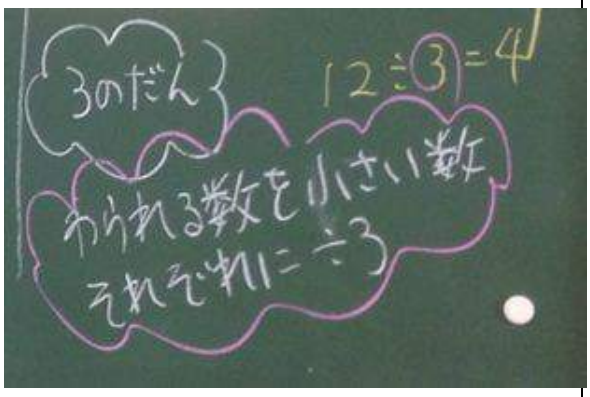
Following these small group discussions students return to their seats to begin the whole class discussion.

<table>
<tr><td>2:04 pm - 220 pm</td><td>3.Presentation of Students' Thinking, Class Discussion</td><td colspan="2">Student Thinking / Visuals / Peer Responses /Teacher Responses
The different colours used within this table indicate different families of strategies that were discussed and recorded by the teacher and the students.</td></tr>
<tr><td></td><td></td><td>Teacher</td><td>Students</td></tr>
<tr><td></td><td></td><td>Teacher asks student who were previously not sure of their answer (scissors or paper) and learned something new when talking to their friends to raise a hand and he then calls a student (S32) to the blackboard.</td><td>Student write 3x6=18 on the board</td></tr>
<tr><td></td><td></td><td>Who can guess what she is thinking?</td><td>Other students: 3x10=30</td></tr>
<tr><td></td><td></td><td>What comes next?</td><td>Other students (only verbally)
3x11
3x12</td></tr>
<tr><td></td><td></td><td>Is that the same idea, how did you use 18? Why multiply? (the teacher is referring to 3x10 and the progression from this into 3x11 and 3x12). The teacher is expecting the students to continue with this progression until the answer is reached however this does not happen.</td><td>This is to find the answer!</td></tr>
<tr><td></td><td></td><td>Teacher calls another student (S21) to continue with the solution.</td><td>Student draws a diagram:
 
This is 3x10, what's left is 18.</td></tr>
<tr><td></td><td></td><td>So we split 48 into 30 and 18.</td><td></td></tr>
<tr><td></td><td></td><td>I'm puzzled here…the teachers moves onto a different strategy without asking the students to continue with the one above.

He cuts each piece of paper into 10 and 2 (see white pieces of paper on blackboard below).

Then he gives one piece with the number 10 on it and one piece with the number 2 on it to each person (happy face) and puts the piece with 10 on it and the last piece with 2 to the right.

But maybe you want to finish this one first(referring to the last piece with the number10 on it as well as the last piece with the number 2 on it).
Teacher calls another student (S24).</td><td>  </td></tr>
</table>

		The teacher makes the connection to the number 12 with the strips by replacing the 10 and 2 strips (put aside on the left) with new uncut strips with 12 on them (orange strips behind the teacher's head in the photo below), and writes 12÷3=4 next to each one.	It is going to be 4 times as much as 12÷3=4 So you work out how many ice creams each person gets from each box.
		We changed 48 into 30 and 18. We changed them into smaller numbers just like we did with the others (referring to the second strategy), righ? So which is the answer?	Teacher goes back to the previous strategy and puts the 10 strips and the 2 strips next to the writing (over the circles with 10 in them). The students do not respond to the question. All students answer with 16.
2:20 pm – 2:23	4.Summary /Consolidation of Knowledge	**Strategies to support consolidation**  (Final board writing) The teacher asks the students to quickly write their reflections.   (Example reflection) Almost immediately he asks students to read their reflections: S1: Large numbers, like 48, can be broken into smaller numbers to divide. S2: Large numbers, like 48, can be divided by using 3s facts to find the answer. The teacher wrote S2's reflection on the blackboard.	

What new insights did you gain about mathematics or pedagogy from the debriefing and group discussion of the lesson?

Our group had many reflections on the relationship between the lesson plan and the lesson that was taught, namely the differences between the two. The teacher's intentions shifted from what he wrote to what he brought to the students, which in our view led to some of the struggles the teacher had in facilitating the lesson. This is a reminder to us of the importance of planning a high quality lesson proposal that can serve as a dependable framework for the actual lesson (while still allowing room for variation based on student ideas and needs.) Similarly we reflected on the importance of a strong goal for the lesson and remaining committed to that goal when teaching the lesson.

We were struck by another insight connected to the teacher's role during the independent problem solving portion of the lesson. During this lesson the teacher did not appear to take sufficiently careful notice of what the students were doing during independent problem solving time. The difficulty of the discussion that followed stemmed, in our view, in part from this issue. Therefore, we are taking with us an insight into the importance of circulating and very intentionally and carefully gathering data, treating the independent work time as an opportunity to see the students' work and ideas before they are brought to the board for the class discussion. This allows for the most valuable board work.

We also gained insights from the introduction portion of the lesson, which extended in many directions. We question whether this period confused students and over-directed their thinking toward certain ideas in place of others. The details of this hatsumon section were discussed among our group and among IMPULS participants, but not really in the school post-lesson discussion. In the lesson plan, the teacher wrote that he wanted to "Carefully devise hatsumon." But he input of the hatsumon was not coherent with the neriage and the matome. The hatsumon was pushing the students in 6 (or maybe more?) different directions:

- The 12:3 = 4 was pushing in the direction of multiplying 12 by 4 to get 48 and therefore 4 by 4 to get 16
- The 4 boxes of 12 was pushing in 2 possible directions:
    - Share each box and have 4 times 4 as a result (similar to the first in some points)
    - Give one box to each student and share the last box (similarity to the last strategy below)
- The reminding of 3 facts was pushing in the direction of continuing the list of multiple of 3 up to 48
- Previous year's fact of 36:3 was pushing towards an additive decomposition of 48 in two possible directions:
    - 48 = 40+8
    - 48 = 30+18 (But the additive decomposition was not really in hatsumon!)

While there was clearly value in those opening activities for engaging the students, it is important to ask about this and all other lessons: does the introduction open the minds of the students to the problem solving experience, or does it essentially close their minds to pre-planned ideas?

Finally, we found the teacher's approach to supporting confused students - inviting them to "spy" on their classmates' work - very intriguing. In the end, however, this strategy fell short for those students. Looking at other ideas without time for discussion and explanation did not seem to lessen their confusion. We are encouraged to think about other ways to creatively support confused students by connecting them with their peers, even if this strategy was not as effective as hoped.

What new insights did you gain about how administrators can support teachers to do lesson study?

Our group reflected that the teacher who taught the research lesson should have been supported more by his team and administrators to set him up for a more effective research lesson. Thanks to this lesson we can see more clearly the value of lesson revisions by administrators and more of a team effort going into the lesson, so that the teacher's ideas are not the only guide for the lesson. In particular, the teacher would have benefited from an exchange with others on the goal of the lesson. Setting a lesson's goal and confirming that every piece of the lesson plan is directed toward that goal is a process that is best accomplished with the help of more minds than one (and especially the minds of knowledgeable administrators).

We saw clearly that in the post-lesson discussion the analysis must focus on the lesson itself - the teaching, the student thinking, and the pieces of the lesson as they connect to the research theme. We felt that this post-lesson discussion was more focused on the teacher and all of his decisions as a teacher. It was not clear what role the teacher's team had played. We are reminded of the importance of the administrators' role in facilitating the appropriate focus - on teaching and student learning, not the individual teacher - for the post-lesson approach.

How does this lesson contribute to our understanding of high-impact practices?

Despite some of this lesson's challenges, we learned a great deal from many of the teacher's teaching practices.

The teacher had built a very strong classroom culture with positive messaging about learning from errors, self awareness around what you know and don't know, and supporting classmates. For example, from the beginning of the lesson the teacher told students, "If you don't understand the question yet that's great that you know you don't understand." Students were welcome to be honest about what they didn't know, which leads to more risk-taking and questioning.

The culture in the class centered in many ways around student-to-student interaction and not only student-to-teacher interactions. Rather than invite confused students to learn from him, the teacher invited students to learn from each other. The teacher encouraged lots of partner talk, which was highly productive; students were quick to stand, face one another, and jump into an exchange about the question posed. This was clearly a result of the environment set by the teacher.

We also learned from the teacher's focus on the steps to a solution, rather than the solution itself. By putting the final solution to the side of the board from the start the teacher made clear to his students that exploring the different ways to calculate that solution is the more valuable aspect of their learning.

June 23: Tokyo Gakugei University International Secondary School *G7

Group report by:
Marlon Ebaeguin, Sheila Evans, Susie Groves & Gerrit Roorda

1. Goals of the lesson

- Students will understand that the slope of graph represents the speed. [Knowledge and Understanding]
- Students will think about how they need to move to create the given graphs and actually create them. [Investigation of patterns]
- Students can explain the relationship between motions and graphs using appropriate words. [Communication]

2. Where is the lesson located in the curriculum unit?

The lesson lies in the sub-unit, *Tables and Graphs*, of the curriculum unit, *Ways to observe phenomena*, in Algebra and Functions. This unit focuses on representing patterns in change in various phenomena. The *Tables and Graphs* subunit consists of four lessons. In the subunit students organize data from a variety of phenomena using tables and graphs so that they can grasp patterns of change in those situations. The first three lessons were on making a box with the largest capacity. This lesson was the final lesson for this
sub-unit.

3. Introduction and posing the task (11:30-11:50)

This lesson is about the correspondence between phenomena (in this case motion) and their graphs (in this case created by using a motion detector). The introduction to the lesson had two parts: Part 1 (11:30 – 11:42): introduction of the device; and Part 2 (11:43 – 11:50): how to move to create a required graph. Both parts are described in more detail below.

3.2 Introduction of the device
It was a quick start to the lesson. The teacher immediately captured pupils' interest and attention by demonstrating the motion detector. By way of introduction, she simply said: "Let's see what happens". Then she started moving in front of device. The graph, produced of the graphic calculator, representing her movement was shown on the whiteboard screen (see Figure 1).

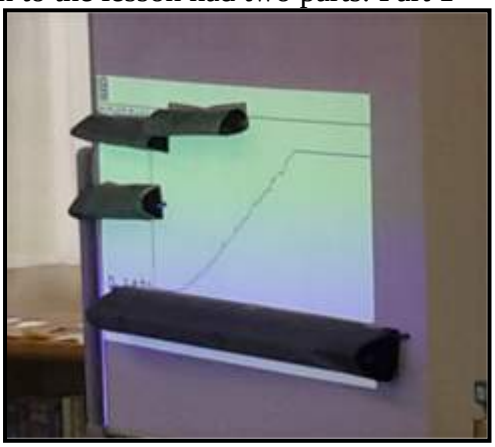


Figure 1. Graph of the motion of the teacher

There was some discussion of what the axes represented, including brief small group discussion (albeit many pupils worked individually). Some students state that the axes represent distance and speed. A student stated that the vertical axis represents distance because it increased as the teacher walked away. The teacher asks what the horizontal axis represents, and a student explained that it represented time because when the teacher stopped time continued to increase, but the teacher didn't move.

The teacher explained that the motion detector sends ultrasounds, which are reflected back, so the horizontal axis represents time and the vertical axis distance.

The teacher then asks whether students could think of an experiment that they could conduct to verify their thinking that the vertical axis did indeed represent distance and horizontal axis

represented time. A student proposed “standing still” – something that was anticipated in the lesson plan together with a statement that it would not be discussed at this point of the lesson as it was something that would be discussed later in groups.

The student predicted that the graph would look like Figure 2.

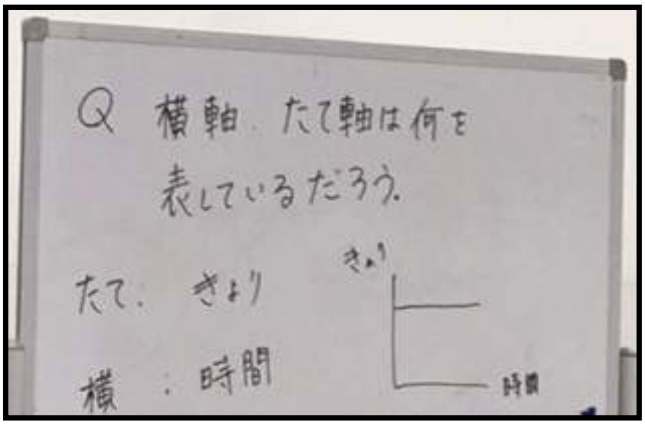


Figure 2. A student’s prediction for the graph produced by a person standing still

The boy stood still in front of the motion detector (Figure 3) and the graph produced was as predicted, leading the teacher to conclude that the vertical axis represented distance, while the horizontal axis represented time.

Figure 3. Boy standing still

Three students, in turn, attempted to represent graph shown in Figure 4 by moving in front of the motion detector. Each made improvements on the former’s attempt. All seemed to recognise that a negative slope represented a movement back towards the monitor, albeit walking backwards. They also appeared to understand that the change in slope represented a change in speed. They also all recognised the fact that the horizontal line in the graph represented no movement, but they only stopped briefly. This did not accurately proportionally fit with the lengths of time taken for the other two sections of the journey.

3.2 How to move to make a given graph

The teacher then posed the problem of producing the graph shown in Figure 4.

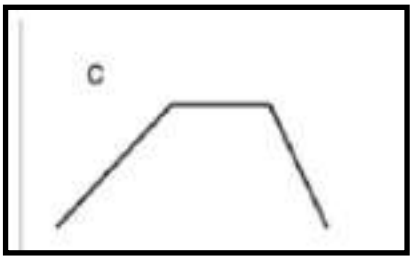


Figure 4. Graph C for students to enact

Figures 5 and 6 show the graphs produced by student 1 (S1) and student 3 (S3). As can be seen, student 3 stood still a bit longer. Both graphs have a high peak at the right. No attention is given by the teacher to (1) what does the peak represent (in fact it represents the distance of a bookcase that stands about 8 meter from the detector) and (2) the scaling of the vertical axis (in fact the device scales the vertical axis depending on the lowest and highest measured distances).

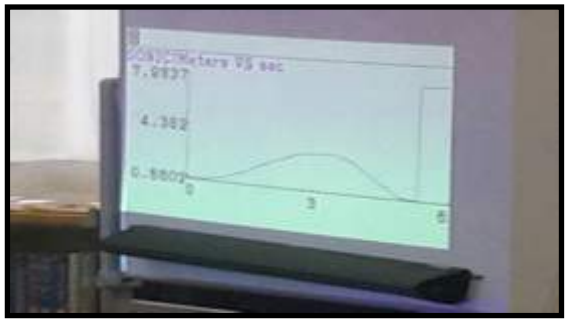


Figure 5. Graph produced by S1

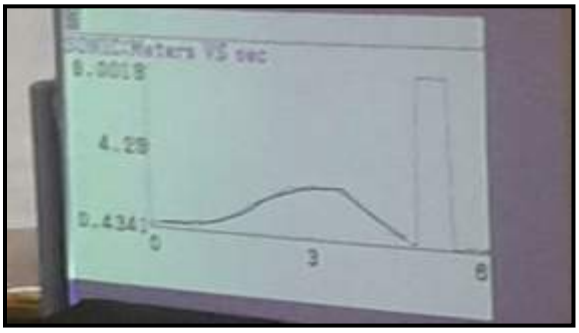


Figure 6. Graph produced by S3

After the experiment the teacher asked the student shown in Figure 7 (the same student as in Figure 3) to explain the meaning of the three parts of the graph. Some attention was paid to the steepness of the first and the third part, with the student explaining that in the first part you walk the same distance in more time. So in part 3 you walk more quickly. Afterwards the teacher summarizes the meaning of the three parts of the graph.

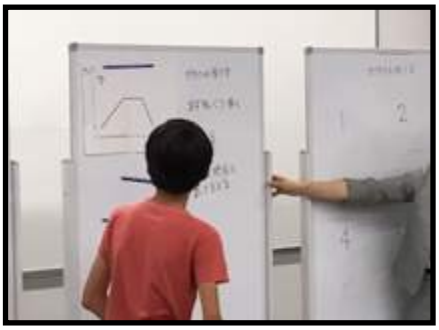
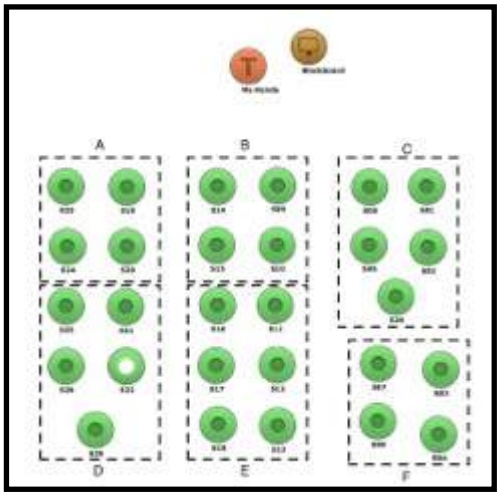


Figure 7. Student explaining the three parts of the graph

3.3 Posing the problem

The teacher posed the following problem:
How should we move so that we can make Graph C (as shown in Figure 8 below). *Please write your idea on the worksheet* (see Figure 9).

Figure 8. Graph C



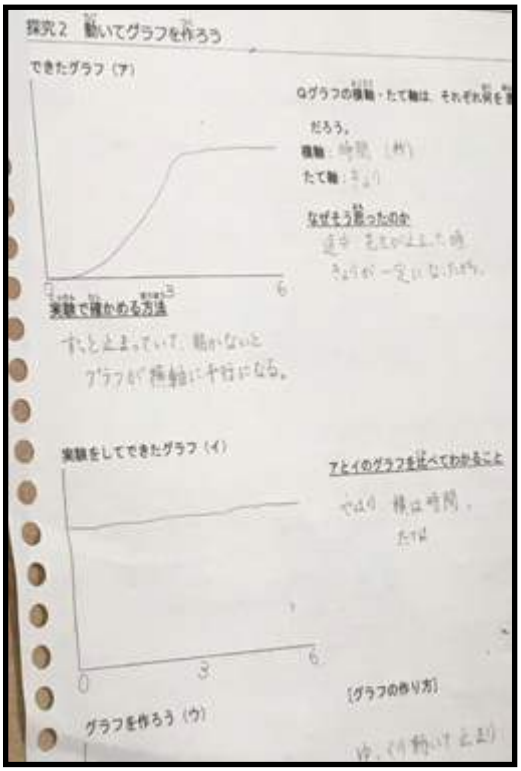


Figure 9. Part of a completed worksheet

The class was divided into six groups, as shown in Figure 10, with each group provided with a motion sensor to use.
The teacher told students to work as a group and that when they felt they had a solution to call her over to demonstrate it.

A student asked whether there were gaps between the straight lines on Graph C and whether the lines were of equal length. The teacher said the lines were intended to be approximately the same and that there were small gaps.

4. Independent problem solving

The team decided to observe one or two groups each. Data is presented below from five of the six groups.

4.1 Group A

Group A were using the teacher's motion sensor so were able to start straight away. Students took it in turns to walk, stop, walk, stop, walk and stop, producing graphs like the one in Figure 10.

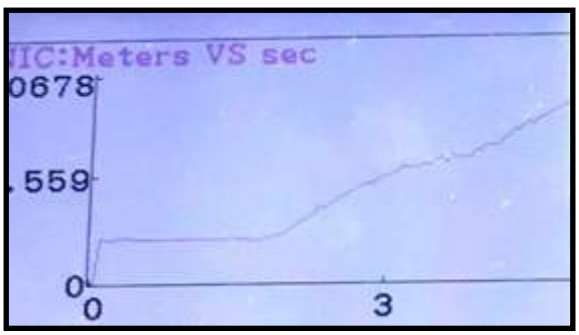


Figure 10. Graph of an initial attempt by Group A to reproduce Graph C

As soon as students saw the graphs and were dissatisfied, they started again, without any discussion or analysis of what might have gone wrong or how to improve the motion.

After some time, students noticed that other groups were using three students to create their graphs. They then tried to have three students in a direct line with the motion sensor (see Figure 11) and have each student jump to one side at approximately equal time intervals. After a number of attempts, they produced the graph shown in Figure 12.

Figure 11. Three students standing in a direct line with the motion sensor

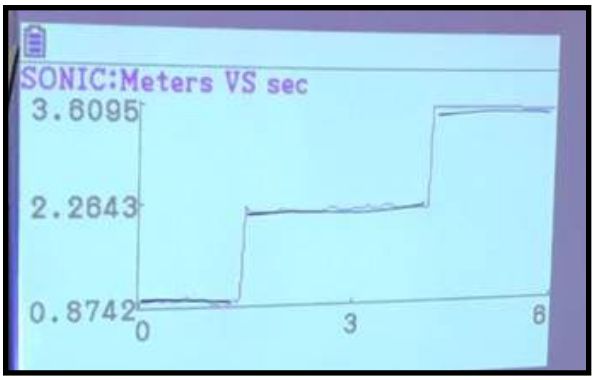


Figure 12. Final graph produced by Group A

4.2 Group B

This group started by lining up three pupils. Unfortunately the many observers hindered the experiment for the group has a problem. There was not enough room for them to stand in a straight line. The group is counting 1, 2, 3, 4, 5, 6 and after 2 and 4 seconds one student steps aside in front of the monitor. The group is not satisfied with the results and they try another method. This time one student is making a walk in front of the detector. They tried to make a quick step forward, stand still, and again a quick step and again stand still. After each attempt, they quickly look at the screen, but unfortunately the graph is not the correct. The student did not take time to discuss the graphs on the screen, but they started quickly with another attempt. This trial and error approach did not result in the correct graph.

4.3 Group C

The group began by three pupils lining up, crouched down at varying, but not equally spaced, distances from the monitor. Starting with the pupil nearest the monitor, they in turn jumped up and then back down. They were not satisfied with the result on the calculator.

They now returned to placing pupils bodies in front of monitor, much the same way they had in 1. However, on this occasion, rather than jump up and down they, in turn, walked through the monitor. We speculate pupils perceived the horizontal lines in the graph as an indication of walking along. On this occasion pupils did pay closer attention to ensuring pupils were equally spaced apart. They then returned to using their hands, but this time three pupils were involved. The time they kept their hands in front of the monitor varied.

Although the trailing did indeed lead to improvements in the graph, there was an element of trial and error within their work. Furthermore the observer's impression was that one student dominated the activity and it was unclear as to whether others understood

Figure 13. A student writing up their work

4.4 Group D

While all the other groups were already trying out their plans, Group D was still discussing how they could replicate the graph. Student 21's (S21) idea was to walk, then wait (stand still), and then walk again. Student 25 (S25) said he's thinking of covering the sensor to show the gaps in the graph. Ten minutes later, the group finally stood up and enacted their plan. Figure 14 shows the group's first attempt.

Figure 14. Group D's first attempt

Group D assigned three members of the group to stand at three different distances from r the sensor, then every three counts one student at a time dropped out of the range of the sensor. Figure 15 shows the graph obtained from this initial attempt.

The graph was no way similar to the graph they needed to produce and even had several peaks. Realising that dropping to the floor in their respective positions didn't keep them out of the range of the sensor, the group decided to make the three members line up and then fall out of line every three counts. On their fourth attempt, Group D produced the graph in Figure 16.

Figure 15. Graph of Group D's first attempt

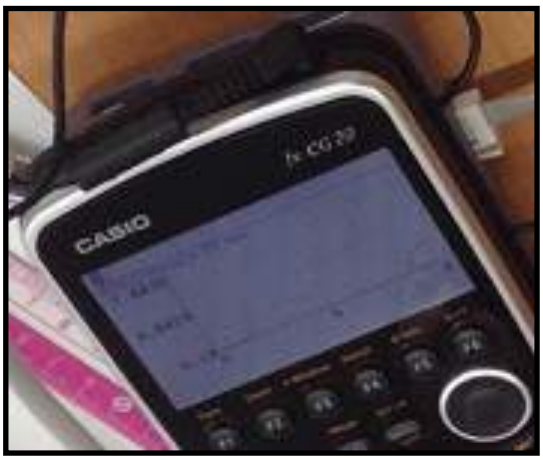


Figure 16. Graph of Group D's fourth attempt

4.5 Group E

Group E's first attempt was to line up three members at different positions from the device, and then, in counts of three, each member, starting from the one nearest to the sensor, "disappeared" by falling out of the line. Student 17 (S17) also covered the sensor every time one member fell out of line. Figure 17 shows the group's initial setup.

Figure 17. Group E's first attempt

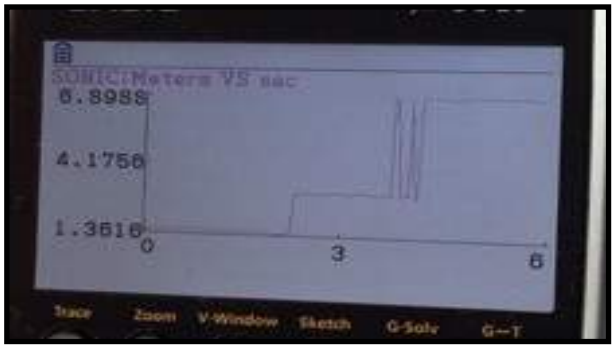


Figure 18. Graph of Group E's first attempt

Figure 18 shows the graph produced.The group obtained a graph similar to the one they were given, except for the two peaks they got. The group tried the same setup working out the timing of the covering of the device and the three members lined up.

Figure 19. S17 covering the device as each member fell out of line

Figure 20. Graph of Group E's 5th attempt

After three trials, the group obtained the graph shown in Figure 20.

5 Presentation of student's thinking, class discussion

After about 20 minutes, the teacher asked Group A to present their results first as they had been using the teacher's motion sensor that was connected to the projector. Their presentation was similar to that shown earlier in Figures 11 and 12. Group E was then asked to show to the class their setup and demonstrate how they obtained the graph (Figure 21)

Figure 21. Group E demonstrating their setup to the class

Figure 22 shows the graph obtained by Group E's presentation. The graph produced was not exactly the same as the graph they obtained using the same setup (see Figure 20) but still had the three horizontal segments the teacher asked them to produce. One clear difference is that gap (third horizontal line) between the second and the fourth horizontal line). The group was a bit surprised why there was a gap when they did exactly the same movements as in their last trial.

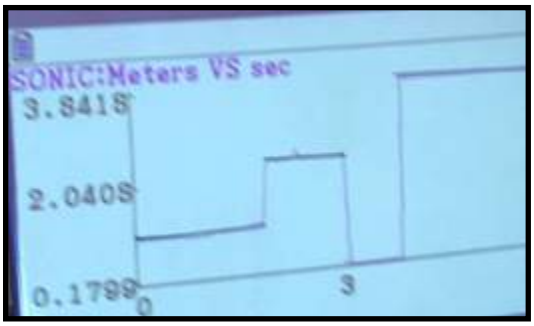


Figure 22. Graph obtained from Group E's demonstration

S22 from Group E wanted to contest Group E's demonstration but the teacher, possibly due to time constraints, proceeded to discussing the graph Group E obtained.

The teacher asked the class to focus on the horizontal segments and what they meant. S29 said that the horizontal lines represented the time the members were standing still. The teacher then asked why there were three horizontal segments. S02 said the three segments represented the three different distances of the team members from the sensor.

The teacher then asked the whole class to write these statements in their notebooks.

The teacher then asked about the significance of the notebook covering the sensor. S24 said covering the sensor with the notebook disabled the device from picking up other motion within its range.

6 Summary and consolidation of knowledge

The lesson plan did not include any indication of a summary by the teacher. Instead, the first of the three goals, *Knowledge and understanding*, is listed as an assessment point at the end of the Introduction section, while the *Investigation of patterns* goal is listed in the Independent problem solving (Investigation) section and the third goal, Communication, is listed in the Class discussion (Sharing) section.

In both the lesson plan, and in the lesson itself, the Summarize section comprised the students writing their reflections on the lesson and the teacher calling on a few students to share these reflections.

The teacher asked students to write in their journals the relationships between motion and graphs and what they learned in the lesson. Figure 23 shows one student's written reflection.

After three minutes, the teacher asked for volunteers to share what they had written or what they planned to write about.

The first student, a boy, said that it is important to think about what movement in the graph represents. The teacher questioned the student as to what he meant by "movement", to which the boy replied that when they had made mistakes they had to figure out what the lines in the graph represented.

The next student, a girl, said that if you have to go from A to B in a short time, you need to have more than one student involved. Initially, the first student's reflection seemed very generic with little attention to the specifics of the lesson. However when the teacher probed for further explanation, the student readily provided her with a more detailed description of his learning. This prompted us to reflect on how important is it for students to provide detail in their written work. Just the act of writing may stimulate them to reflect more deeply than is evidenced in what is in their notebook.

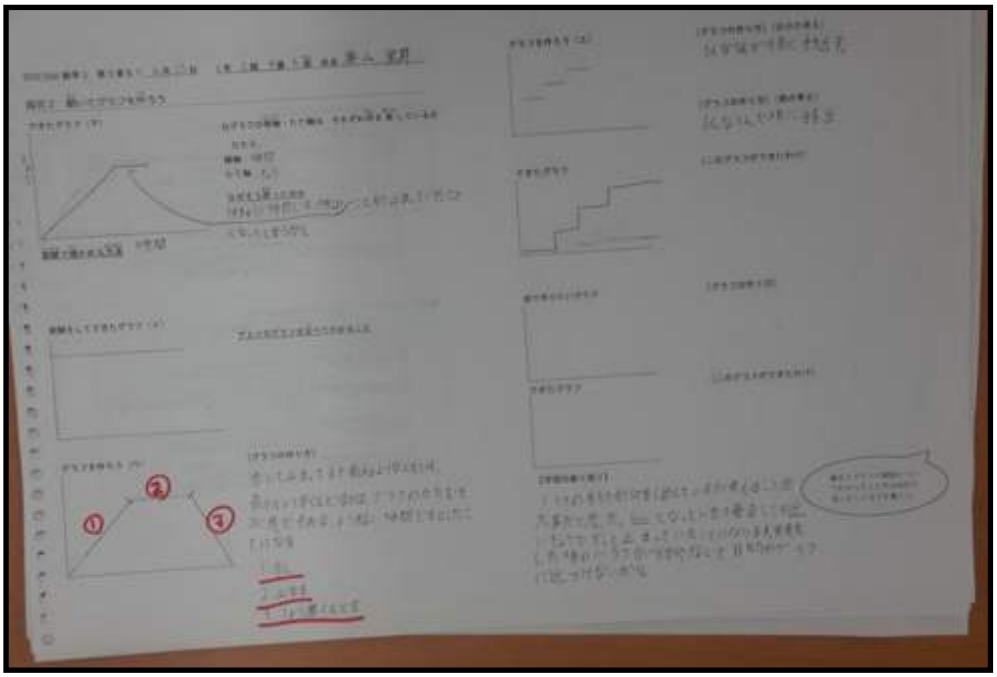


Figure 23. A student's reflection in their notebook

7 New insights gained through the post-lesson discussions

This lesson was not an actual research lesson, but a "regular" lesson that was made open for observation by the IMPULS participants. However, the teacher wrote her lesson plan in the format of a research lesson and the IMPULS participants took part in a fairly brief post-lesson discussion.

One participant commented that this was the first lesson we had observed where "we could see learning taking place".

Nevertheless, there were a number of issues raised about the lesson and suggestions made for

possible changes. These are summarised below.

Understanding that the slope of graph represents the speed

This was the first goal for the lesson, but was mainly dealt with in the Introduction, which was quite short and didn't explore fully this notion. Participants suggested that rather than explore standing still in the introduction, it would have been better to have explored walking faster or slower, as discussed in the lesson plan (see also Figure 24).

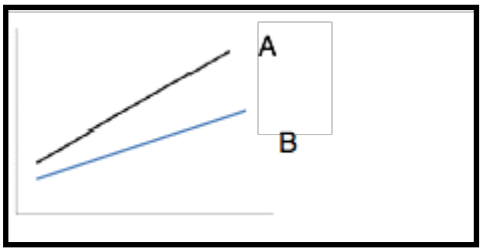


Figure 24. Anticipated student prediction for graph of slower walking

The first student reflection that was shared at the end of the lesson highlighted the importance of thinking about the meaning to be inferred from the shape of the graph – i.e. linking the motion with its representation by the graph.

Technology issues

For these students this lesson was, as far as we know, the first lesson with the motion-detector. In the post lesson discussion comments were made on the technical aspects of the device. As can be seen in Figures 4, 5 and 8 graphs on the screen have peaks and dips. The device automatic scales the vertical axis depending on the lowest and highest distance measured. For example in figure 5 the student starts walking at 0.434 m.
After finishing his walk, the student moved out of the line of sight for the motion sensor, and at that moment the detector measures the distance as 8.0018 m – in this case a bookcase. During classroom discussion the teacher didn't discuss why the graph had a peak of about 8 metres. Also the dip of the graph in Figure 10 was not discussed in the classroom. In the post-lesson discussion, Professor Takahashi emphasized the importance of understanding the technical aspects of the device.

For the understanding of the graphs on the screen it is necessary that students discuss the scaling of the vertical axis. This remarks fits well with another comment, namely that students need more time to get to know the technical aspects of the device.

8 How this lesson contributes to our understanding of high-impact practice

In this section, we will summarize some of the views of different members of our group on this topic.

Collaboration

Within this lesson students worked on the problem in groups. Research consistently demonstrates that collaboration can enhance learning. However research also shows this rarely happens in many classrooms. Likewise, we were left with the impression within this lesson that pupils failed to collaborate well. In the groups we observed, it appeared that just one or two students dominated the activity. However, because of our lack of Japanese, it is difficult to say with any certainty the

reason for this. We know from the research in the "West" that pupils need more than simply the provision of an opportunity to work together. They many not engage optimally in a task if they believe someone else in the group will take responsibility for the work. This is particularly the case if a team member with an established reputation for being "mathematically able": others may be inclined to uncritically accept their thinking, instead of participating in a productive exchange of ideas. Moreover, if group members, for example, can solve a problem individually and if their goal is performance, then there is little motivation to collaborate. They may even risk performance deterioration due to the cognitive costs of coordinating different approaches to a problem.

We speculate, for this lesson, that by slowing down the process of experimenting, checking, experimenting again, may promote better collaboration. For example, as Akihiko Takahashi suggested, printing out each graph, may help students move away from a "guess and check" approach to the task. By asking pupils to figure out together what needs to be improved and how this could be undertaken, may prompt them to mutually engage in the decision-making. These explanations could be recorded as annotations on the graph. The explicit monitoring and regulating of their "solutions" can promote socially shared metacognition.
Moreover, without the printouts and the recording of decisions made, evidence of progress has an ephemeral quality. Making it challenging for both student and teacher to productively reflect on their learning. *Importance of coherence between mathematical goals, activities, and summary of the lesson*

While student learning was clearly apparent in this lesson, there was a lack of clarity about how the main mathematical goal – which could be considered to be an amalgam of the Knowledge and understanding and Investigation of patterns goals – were pursued in this lesson. These two goals refer to understanding "that the slope of graph represents the speed" and that students should "think about how they need to move to create the given graphs ". However, most of the lesson focussed on standing still, with some participants also questioning the graph being produced by three students as being characterised as "motion". A clear plan for how this main goal would be realised and communicated to students would have enhanced this lesson.

June 23: Tokyo Gakugei University International Secondary School *G9

Group report by:

Dean Rowley, Shelley Marie Terzian and Brent Jackson

What are the primary lesson goals?

Students to experience and understand the merits of random sampling and develop the disposition to make use of what they learned in their own future project which will require the use of random sampling. The second goal of this lesson is to provide opportunities for students to communicate and improve their ability to use statistics in communication.

Where is the lesson located within the unit (in relation to previously studied topics and ideas to be studied in the future)?

There are a total of five lessons in the unit, Analysis of Data, and this is the third lesson. In the preceding lessons students try to create a sample that they believe will be representative of the population (named an intentional sample) as well as a random sample. After this lesson, students continue to discuss sample survey methods in the context of the unit's main problem and their project.

In previous units, students have studied the measures of central tendency. However, students have not studied distributions or variance. Some students have studied probability, but not formally.

Start & End Time	Lesson Phase	Notes
0:00 - 4:00	**1. Introduction, Posing Task**	**Strategies to build interest or connect to prior knowledge** • review of the previous day's circle task • presentation of tabular data that includes each groups' calculated means from the random and intentional (non-random) samples • teacher asked "What are good methods to draw samples? Use the data to find an appropriate method." • Students were given the data on a print out and in an excel file. The lesson's design is based on how statistics is performed and interpreted, so that students can experience its usefulness. Students have been exposed to the mathematical concept of intentional and random sample discussed during this lesson prior to today's lesson. For example, students learned about sample survey and random sampling to meet the above goal of this lesson. Further, students have learned basic descriptive statistics. In addition, the teacher writes in the lesson plan the connections to prior knowledge. For example, the teacher will remind students that they had previously calculated the average area of the circles using random and non-random (intentional) sampling. Also, important math terms such as means, sampling, intentional or non-random sampling, and random sampling.  The teacher pulled together each students mean determined by the random and non-random sample the previous day and organized this data into two tables by student number. (The students were given two tables of data - one with a list of every student's' calculated mean from the non-random sample and another table with a list of every student's' calculated mean from the random sample). The class quickly reviewed these tables to understand what they represent from the previous day's work. The teachers asked if any students calculated the actual mean by taking a census of the circles. One student had so the true meanwas shared with the class and the teacher confirmed that this was the actual mean. Next, the teacher asked the students to work together to answer, "What is the most appropriate method to create a sample?" Students were expected use these data sets to determine whether the random sampling is better or whether the intentional sample was better by comparing to the actual mean. Students were expected to devise their own way to make sense of the data and represent the data.
4:00-15:00	2. Independent Problm-Solvin	−**Individual, pairs, group, or combination of strategies?** −Experience of diverse learners − Teacher's activities Students worked within groups of 3 or 4 on the task of "What the most appropriate method was to create a sample?"

	g	Two groups looked at finding the mean of each of the methods and how this related to the mean of the population. A third group looked at finding a representative sample of 5 circles and then comparing their answer to each other (although they did not find the population mean within the time frame). Fourth Group spent time discussing the methods from the lesson before and their understanding of random and non-random (not much work produced but discussion helped by translator). This group interpreted the task as a challenge to find a way to intentionally sample and a way to random sample that both provide appropriate sample means. Fifth Group spent all of time finding the population mean alongside discussion of different types of circles and how this affected their sample. Within this time the teacher moved around looking at different solutions but concentrated his attention to 4 individuals within the room.   
15 - 48	3.Presentation of Students' Thinking, Class Discussion	Student Thinking / Visuals / Peer Responses /Teacher Responses Photos to document chronology (use new box for each new student idea presented] Presentation of students' thinking: 1. 5-7 students actively involved in discussing their findings as to which method is more useful- random or non-random sampling. 2. Teacher questioning before, during, and after the lesson. 3. Organizer/note sheet for summarizing findings 4. Data set 5. Circles **Student 1** **Census** Determine the mean for all of the circles and then determine which method yields a number closest to the mean. Compare the two methods to find which gets us closer to the mean more often. The method that gets closer more often is the more appropriate method. **Student 2** **Mean of the Means** Determine the mean of all the circles. Calculate the mean of the random samples and calculate the mean of the intentional samples to find which mean of the means is closer to the actual population mean. **Student 3** **Be More Intentional**

		Identify all of the different types/sizes of circles. Then consider the number of each type and intentionally sample in the proportion of the known population. "Make our intentional samples, which were quite random, less random by intentionally sampling each size of circle in proportion to the circle population." **Discussion** This discussion centered around presentation 3. There was debate about whether intentional and random sampling was better. There were about seven students that were main contributors to the discussion. It appears students were confused about the definition of random versus definition of intentional. Students argued that their intentional samples taken the previous day were actually not very intentional and therefore quite random. Students hypothesized that if they thought about the population they could be more intentional about their sample which would yield a result closer to the actual mean. Students also argued that random sampling could be a bad idea because the randomness might accidentally sample all "big circles" but there are actually more small circles in the population. This idea was expanded upon to say that in their more intentional sample, they should use more of the smaller circles. One student responded to say that the randomness of the random sample would likely choose more of the small circles, but other students did not pick up on this idea.
48-50	4.Summary/Consolidation of Knowledge	Strategies to support consolidation, e.g., blackboard writing, class discussion, math journals. _teacher facilitated, threw questions back at students _summarized when student said confused about the conversation _student handout

What new insights did you gain about mathematics or pedagogy from the **debriefing and group discussion of the lesson**?

The debrief of the lesson spent a long time discussing the content of the examples shown and how they did not relate to the overarching student performance goal of the unit. That is to say, the skills within the lesson would not help students develop surveys to sample in the situation where the general population is unknown.
The technical understanding of random sampling and how to improve the student understanding of this crucial skill in statistics was not developed by the teacher through his use of examples and this was explained by some of the teachers in the post-reflection session and also through the use of the knowledgeable other.
Essential learnings from the debriefing of this lessons:
-When designing lessons, each lesson (and tasks within lessons) should be considered within the context of the larger student performance goals. In this case students are going to have to sample a population where they don't know the general demographics when sampling.
However, in this lesson the students had access to know the general demographics of the circle population.
-Be mindful of language issues around random versus intentional sample. In students minds their intentional sample was quite random.
-Student agency - discussion was mainly between students and the teacher spoke very little. Towards the end of the lesson a student asked the teacher to summarize because he got lost in conversation.

-trajectory of learning. Why is variance not taught or discussed within this task? It seems variance is an important notice in order to know that histograms and other graphs that represent variance are appropriate to decide which is best.

What new insights did you gain about how administrators can support teachers to do lesson study?
Although not seen within the post lesson discussion, the sessions did highlight the need for support with planning for this content within the curriculum and further development of appropriate examples and pedagogy of the teaching of random sampling and what methods to use for unknown populations. For example, the outside expert during the planning phase might help the team to see how the lesson fits into the wider curriculum and goals through different lenses (i.e. Issues of equitable participation, ensuring the mathematics is connected and coherent). It is important for administrators to be involved in lesson study to know where teachers might struggle during the lesson so that the appropriate knowledgeable other can be acquired.

How does this lesson contribute to our understanding of high-impact practices?

The lesson showed that without proper planning and dedicated time to thinking about learner understanding and pedagogy teaching this topic is quite difficult. There is a crucial need to ensure that planning is developed and checked thoroughly to ensure that terminology is accurate and appropriate for the lesson alongside being related to the overall aims of the unit.

The teacher was able to elicit student ideas and facilitate a discussion among students. These are two core practices for effective teachers. However, this lesson highlighted the importance of the teacher being able to respond to and capitalize on student ideas to help meet the learning goals of the lesson. At the beginning of the lesson, two strategies were shared that would helped him make progress towards the goal and effective monitoring of students ideas during the student work session and careful sequencing of the ideas might have helped . (The tension here is that is would have censored some other students' thinking. With careful monitoring it may be possible to know before the sequenced presentation of student ideas who is struggling. The struggling students can be strategically called on in ways that will help them make sense of the more productive students ideas being presented.)

June 24: Ryuo Elementary School

Group report by:

Trinity Thompson, Jan Parry, Pauline Tyson, Rachael Horsman, Marna Wolak

What are the primary lesson goals?

To

- Develop students' understanding of the units of volume as well as the formulae for calculating the volume of cubes and rectangular prisms.
- Develop the interest in volume of solids and nurture the disposition to think about ways to determine their volumes.
- Extend students' ability to solve problems independently by making use of their prior learning.

Where is the lesson located within the unit (in relation to previously studied topics and ideas to be studied in the future)?

In the Grade 2 unit, "Length and Capacity (Volume)," students learned about the concept of length and capacity as well as the relations among units through activities to measure objects using the units such as centimeter, meter, deciliter and liter. In the Grade 4 unit, "Ways to Measure and Express Area," students learned the concept of area. They also learned that, since the area can be expressed using the number of unit squares, the area can be calculated using the length of sides of the figures. Concerning the "Basic Solids," students have learned about rectangular prisms as the basic solids and the size of a rectangular prism is determined by the length of their sides, - length, width and height for rectangular prisms and a side for cubes. On the other hand, there are students who can calculate the area of rectangles and squares using the formula even though their understanding of the concept of area is rather weak and lack quantity-sense.

In mathematics lessons, I have been emphasizing individual problem solving by providing students with ample time for independent problem solving during Mondai Kaiketsu Gakushu style lessons. As a result, an increasing number of students are beginning to use their prior learning and express their ideas accordingly as they engage in problem solving.
In this unit, students are expected to develop the concept of volume through activities to measure the volume of rectangular prisms by selecting appropriate units. The aims of the unit also include developing students' ability to measure volumes and enriching their quantity- sense with respect to volume. Students are expected to develop the ability to calculate the area of volume based on their understanding that the size of solids are determined by the lengths of their edges.

The process of deriving the formula to calculate volume of rectangular prisms will be emphasized in teaching of this unit. For that purpose, lessons will be developed based on Mondai Kaiketsu Gakushu format. It is intended that students will recognize the merits of generalization and derivation of the formula on their own. When they do, their understanding of the meaning of the calculation of volume will be solidified. At the same time, by incorporating activities to empirically determine the volume of solids by filling the figures with unit cubes, students' quantity-sense with volume will be enriched.

Start &End Time	**Lesson Phase**	**Notes**
2pm	**1. Introduction, Posing Task**	**-Strategies to build interest or connect to prior knowledge** -Exact posing of problem, including visuals Teacher begins, ‘We’ve been studying volume of solids; of which shapes can we find the volume?’ Children chorus the reply, ‘cubes, cuboids’. Through questioning, teacher elicits information and records on the board to revisit prior knowledge of formula for finding the volume of cubes and cuboids. (sometimes restating children’s contributions, modelling precise use of mathematical language) Also mentions that volume of cubes can be found in the same way as cuboids, but that all the edges are the same length. Shows an image of the new shape. Teacher asks, ‘Is it a cube?’ ‘No!’ ‘Is it a cuboid?’ 

		'No!' Children decide to call the new shape the 'step shape'. Teacher states that the problem today is finding the volume of the step shape. He records this on the board and students copy this goal into their books, putting a blue box around the goal. Teacher restates the goal for today, finding the volume of the step shape, and tells the children that they have 3 copies of the 2D image of the step shape on their desks, so they can try and find more than one strategy for finding the volume of the step shape. He tells them that they can use anything they like to help them solve this problem, they can draw on the image on the paper, they can do anything they like. He states that he is expecting them to come up with as many different ways as they can to find the volume of the shape. The children begin working on the problem individually, and the teacher begins circulating, holding his paper copy of the seating plan, jotting down a record of different strategies, making comments to some pupils (not translated)
2.05pm	2. **Independent Problem-Solving**	**-Individual, pairs, group, or combination of strategies?** -Experience of diverse learners  This was a 3D concept, albeit after some groundwork lessons on cubes and cuboids, the teacher used very few manipulatives (concrete materials) apart from a cube and cuboid which he held up as a reminder of the previous session and a model to show the fourth strategy. Pupils work independently on the problem. Many can be seen trying to draw line on a copy of the diagram, changing their minds, rubbing out lines and trying again. However a number fail to get started and with no manipulative\concrete support to help them visualise the problem do not produce a solution of any kind. Some of the children seemed to be following a set pattern of solutions for this volume problem suggesting that perhaps they had 'learnt' without understanding from work on area of composite shapes at an earlier stage. At one point the teacher suggests an answer that he has seen several times before – this creates a variety of reactions, from surprise, to agreement, to puzzlement, but it does seem in a lot of cases it motivates the pupils tot keep going. Once the majority completed one method - splitting,(but some have incorrect calculations by miscalculating missing edges) the teacher sendS the diagram to their individual iPads and asks them to show their ideas. He looks at his own screen with copy of all iPads and intervenes with those who haven't written anything yet to encourage them. Any who have one complete method are asked to find a second. Roughly 7 or 8 pupils complete the problem by subtraction, 1 by translation (slightly incorrect), the Rest by split it into two cuboids. - Teacher's activities The teacher used the iPad system well and it was an excellent way of supporting the students in their feedback. A moveable 3D object that could have been turned around on the screen to give the students more of a support with their visualization would be a huge benefit. During the problem solving phase the teacher moved around the right hand side of the

		classroom leaving two or three students on the left hand side unsupported; it's unclear whether this was due to his previous knowledge of the class or linked to the fact that supporting teachers had been allocated specific pupils to observe. Scanning classes to identify students who are not engaged with problems doesn't seem common practice in Japanese classrooms.
2.25pm	**3.Presentation of Students' Thinking, Class Discussion**	**Student Thinking / Visuals / Peer Responses /Teacher Responses** Photos to document chronology (use new box for each new student idea presented)  Looking at the overview of the IPads, the teacher chooses a pupil who uses the method was forecasted in the lesson plan.  **1st idea** The first pupil explains how they worked out their answer. They are asked for a clear argument and to develop their own language to name the two cuboids formed through a cut; left and right. As he is doing so the pupils IPad is projected on the screen and he can add information to the diagram. Each step is linked back to previous knowledge and led by pupil with the teacher restating using clear correct vocabulary including the line segments e.g. Line DE The teacher shows the cut on a copy of the diagram. Having received an overall explain action (no calculation) the teacher writes an explanation in words, He then asks for expressions/calculations – a different pupil gives these again detailing what each steps represents and finishes with the answer being identified with it's units.  Each step is carefully clarified, each calculation explained (including missing length) and others are included in the discussion. The teacher reviews the process at the end.

A couple of pupils register recognition and one states that he's done it the same but different.

2nd example

A second pupil is asked for the equations. She asks "just one?" the teacher replies " Just separately"

She replies (and they are written on the board as she says them)

8x4x2=64

8x9x4=288

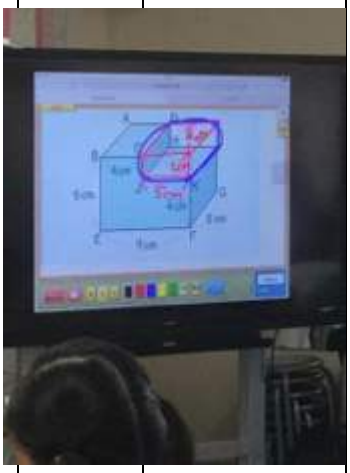
64+288=352cm^3

The class immediately study their own work and copies of the diagram. I few show recognition. The teacher asks for someone to explain what she did. Everyone looks at their diagrams and thinks about what she/he did, hands start to be raised.

The pupil asks to explain her own ideas....she goes on to explain with use of iPad

Teacher models solution on the board, adding a copy of the diagram, showing the cut and writing a few words to explain. A few copies ideas into notebooks

The teacher asks;
"Which equations are for the top and which for the bottom?"
"Where's the 2 it's not in the picture?"



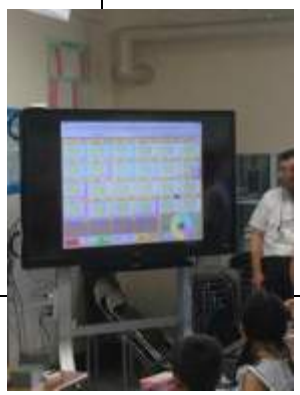
On each occasion a different pupil is chosen to explain clearly the answers to these. Pupils explain, the teacher reiterates and shows it on this copy of the diagram

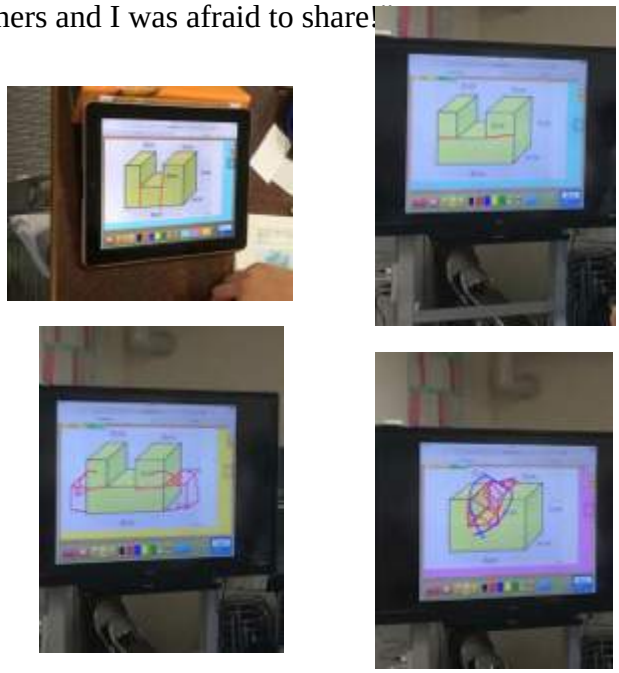
3rd Idea

A third pupil is chosen. They explain that they pretended an extra cuboid was there, that they found the volume of the big cuboid, then smaller gap part and then subtracted. Whilst doing this she shows her idea on the IPad

The teacher yet again reiterates with questions about the method. He models the solution on a third copy of the diagram, writes a brief explanation in words, constantly questioning and asking for members of class to explain

Different pupils offer the equations and explanations of the equations that he summarises in clear language

		(including using the line segment labelling)  **4th idea** A final solution is sought. A pupil (without showing their diagram) is asked to read out his equation; 8x11x4 Many in the class are stunned. Where did it come from? They are give some individual time to work on their own diagram to discover where this came from. The original pupil is returned to and explains his method. He uses clear labelling for the edges and his iPad to show what he means. The teacher asks the pupil to come to the front and reveals a physical model of the 'step' and asks the pupil to show what he means. Having this model in front of  them and seeing it happen absorbs pupils and they are intrigued by see it in action The teacher then returns to the equation given, as a class they work out on diagram where individual terms came from, he marks on the diagram, writes in words what was demonstrated, demonstrates as writing, and finalises the answer. At each step checking that pupils are happy by asking individuals for their idea or generally asking for agreement. The teacher then names methods and labels them (colour coded); Split (*2) Add and subtract Move or transform He asks "What do the have in common?" Pupils say that "The answers are the same" The teacher responds that most likely then all the methods are valid. Another pupil offers that "All of them are finding the volume using the cuboids" The teacher states that that is the summary for this lesson, and he writes an initial summary phrase on the board that pupils elaborate on in their books.
2.50pm	**4.Summary /Consolidation of Knowledge** 	As mentioned above, the teacher reviewed the different strategies of splitting the cuboid that had been shared by students and presented on the board and colour coated. The teacher then asks if the pupils think they can find other volumes. He has a challenge for them. He sends a new shape to the IPads. The U shape is sent to pupils on their IPads and they are asked to vote for the colour method they would use (match earlier named cards). Pupils vote and the results are projected – a lot chose the translation method. Pupils are then asked to draw line on the shape to show how their method

		would work – and then check that their line matches the method, therefore showing their understanding of the method and rationale. A couple of ideas are discussed in the same order that the original problem was solved; two splits, takeaway, translate. At the end of the lesson students are asked to complete their reflection in their journals. We were unable to view any of the students' reflections, however, in the Post-Lesson Discussion, the teacher shared some of the students reflections, such as, "I could see that there were many ways of solving this problem." Additionally, "I had an answer, but there were many foreigners and I was afraid to share!"  Finally the teacher highlights, following a pupil comment, an issue with translations – that the heights have to match

What new insights did you gain about mathematics or pedagogy from the debriefing and group discussion of the lesson?

- Review of strategies learned past: During the post-lesson discussion the teacher discussed that the calculation, not the idea, was where many students struggled. In this case, modelling the process of calculating a regular cuboid could have helped students get started once they came up with their strategy for splitting shapes.
- Share out problem solving strategy options BEFORE independent solving time so that everyone has a way to approach the lesson.
- Ensure students to use mathematical terms when communicating their understanding.
- Ensure that students are sharing expressions using the correct language for length, width and height
- Provide small physical models or other 3D representation of shape to students
- Being comfortable with purposeful departures from lesson plan: extension of problem solving time based on the number of students who needed it.
- Compare and contrast strategies at the end to create understanding of their usefulness.

What new insights did you gain about how administrators can support teachers to do lesson study?

- During the post-lesson discussion, the principal explicitly asked the knowledgeable others to address certain topics that teachers were still struggling to understand or wanted more strategies to use.
- Providing and encouraging the use of technology in their school: IPad aided academic learning and assessment by allowing ALL students to represent what they were thinking and contribute to the lesson. They also demonstrated their learning by using it for the follow-up problem.
- Assign a scribe for research lesson: Research lesson notes (teacher words and student work) were typed up and shared with faculty and knowledgeable others before post- lesson discussion
- Assign focus students for observation: Teachers were made to observe certain students in the class so that they had people to share about all students
- Summary: Facilitator chose and reported out about elements that the school would focus on moving forward and how they would utilise their learning process.

How does this lesson contribute to our understanding of high-impact practices?

- Follow-up lessons should address misconceptions: Based on the classroom vote conducted with the iPads, the move/transform strategy was clearly the classroom favourite at the end. Not much conversation was dedicated to sharing out when this strategy can be utilised. It is important that follow-up lessons will share non-examples of this strategy.
- Reading out reflections as evidence of learning at the end of the lesson
- Know your focus: Because the point was not to correctly calculate the volume but find ways to find volume, sharing out of volume calculation answer (352cm^3) to whole group during problem solving was a great way to create more motivation.
- Allowing students to name the shape created interest/motivation
- Use of different colours in Bansho to represent different concepts or strategies.

June 25:University of Yamanashi Attached Elementary School *G1

Group report by:

Sui Lin GOEI, Megan Mahoney, Brigid Brown,
John Christopher A. Aragon, Crystal Ramirez, Rebecca Setziol

What are the primary lesson goals?

The goals of the lesson are that students will grasp comparison-difference-unknown situations as subtractions situations by relating them to separate-result-unknown situations. They can represent the situations using pictures, words, and block manipulation.

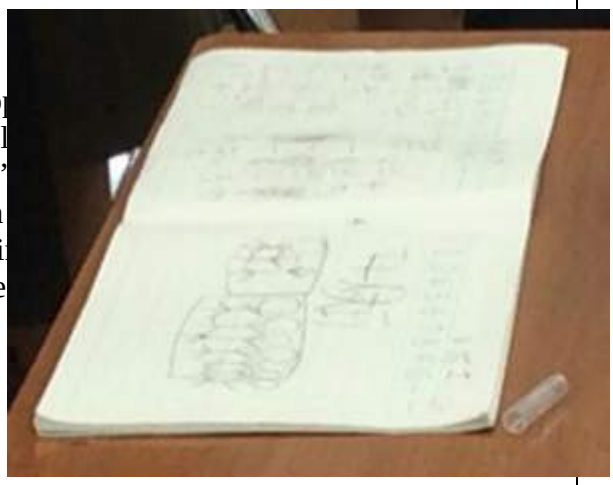
Where is the lesson located within the unit (in relation to previously studied topics and ideas

to be studied in the future)?

This is the fifth lesson in the unit which is comprised of a total of seven lessons. Students started with understanding the meaning of subtraction in separate-result-unknown situations and then moved to understanding subtraction in the PPW-Part-Unknown situations with the minuend of 10 or less. Next, students moved to understanding the meaning of subtraction with 0 and then the research lesson. The lessons following the research lesson include deepening the understanding of subtraction in comparison-difference-unknown situations and creating their own subtraction word problems.

Start & End Time	Lesson Phase	Notes
	1. Introduction	**-Strategies to build interest or connect to prior knowledge** At 8:59am Mr. Yamaguti began the lesson by asking the students what games they have been playing since it has been raining. Hands shot into the air and he called on several children. Then he told them he was going to show them a video of themselves playing dodge ball. The students were very excited and were audibly delighted when the video clip came on the screen. The teacher asked, "What are you doing here?" The students replied that they were playing dodge ball and that the blue team won. Then he asked them to explain how they knew that the blue team won the game. The studentsexplained that the team with the most players wins the game and the blue team has 7. Some students then shared how they counted the players (counting by 2s, ones). Mr. Yamaguti then wrote the problem of the research lesson on the board and asked which team won?  **There are 7 players on the Blue team. There are 3 players on the White team. How many more players are there on the Blue team than on the White team?** Students respond that the blue team won to which the teacher responded, "How many more does the blue team have?" After the answer was shared, the teacher asked the students to name the strategies they've used so far to figure out the answer: counters, blocks, words (what kind?) sentences, pictures, and circles, splitting, and putting to one side. After 7 minutes Mr. Yamaguti asked, " Can you solve this problem using the methods we've used?" and the students transitioned to working independently.
	2.Independe nt Problem-Solving	**−Individual, pairs, group, or combination of strategies?** −Experience of diverse learners − Teacher's activities The students worked independently on the problem for the majority of the lesson; however, students did have the opportunity to share their ideas with their classmates. All students were given the opportunity to share their ideas with their table partner. About 7 students were given the opportunity to share their ideas or the ideas of their classmate in front of the class at the white board. Although we were unable to circulate the classroom because of limited space, we were able to observe the work of several groups of students including a group of

students that were sitting in the back right side and last row in the middle/right side of the class. There were several strategies that we observed from the students.



*Draw a picture

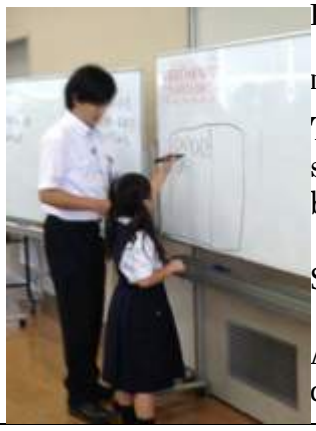
The first student seen below drew peo
each team. He then took out his manipul
up 3 blocks under those blocks. We don'
after that so there was no expression
anywhere on his paper as you can see i
drawing pictures and using manipulative

*Write numbers

The next strategy We observed was a student who used pictures to represent the people. He also numbered each person in order to keep track of how many people were on each team. He also separated the team in 2 separate boxes, we think, to also help with the organization of his pictures. We believe he was able to visually see the difference in the teams in his drawings and was later able to write the expression for the problem.

*Draw segments

The last strategy we observed was a student who drew circles to represent the number of players in each team. He lined up one team under the other and later connected the top circles to the circles that were under that circle. He then counted the number of circles left over and circled the remainder.

		There was another student who erased her work two times to write what others had written. First, she drew circles and numbered them. Then, she erased the work and drew different circles and connected three pairs with line segments. It seems like she made the change after she saw that strategy from another student. She then drew two circles around two groups of 4 (see image below). She seemed to get confused by the drawing and then ended up erasing the entire drawing and redrew the image without circling the groups of four. We observed that several students, including the girl below, erased their initial diagrams to draw the diagrams from their classmates. The student below originally drew a diagram with numbered labels. Then, she erased the diagram and drew the circles with segments connecting the two groups. It seems like the students who erased their original work thought that they needed to have the same work as their peers.  
	3.Presentation of Students' Thinking, Class Discussio n	**Student Thinking / Visuals / Peer Responses /Teacher Responses**  Photos to document chronology (use new box for each new student idea presented] The board work began with the teacher inviting a student up to the board to draw a strategy on the board. Student 19 was invited first to draw her diagram. After completing her diagram, the teacher asked her to confirm that the diagram on the board matched her

notebook model.

She drew a diagram with seven kids and then three in a second column. After drawing the kids, she circled four of the seven. The student told the teacher the four circled was the answer. In the picture above, the teacher is helping the student connect to the prior learning by having her identify the type of model she has used. Then the teacher asked the class, “How can we tell she knew there were four extra players?”

The teacher then asked who thinks they can make an improvement to the diagram.

The class continued to discuss openly how Student 19 knew there were four extra players and the class responded with such comments as:

- She counted the circle of four
- [the diagram] says there are three on the white and four on the blue

But aren't there seven on the blue team.

Student 40 came up to the board to draw her diagram. The teacher held her paper for support as the student to draws here diagram. The student draws a row of seven kids and below that row, she draws another row of three. She then proceeds to draw connecting lines between the three kids on the white team to three of the seven on the blue team (see the image below).

The teacher then poses questions to the class about how they see this diagram as an improvement and with the classes help, he labels the diagram.

The class offers such information as:

- All [kids] are lined up
- Maybe we can draw arrows
- She made it two rows
- She is drawing lines to connect
- It is easier to count (when lined up)

The teacher asked the class during the discussion such questions as:
How do you know the answer?

- What is the improvement?
- Why is it easier to seem when lined up?
- How do you know the answer?

The teacher then calls for another student to the board to invite share what more improvements were noticed. The student said that she connected the lines as she points to the diagram on the board. She then explains that the players not connected are the extra players.

Another child was invited to explain how, based on the models on the board, he knows the answer if four. The teacher asked, “why is it easier when they are all lined up?” and the student responded, “The blue team is lined in 2 rows (the first model) and (the second model) is easier to count.”

The child is able to compare both diagrams. While the children share their ideas, the teacher models how to label the model to make the student’s thinking even more clear.

Then the teacher restates that the way the student 40 lined up the numbers was better and the class agreed.

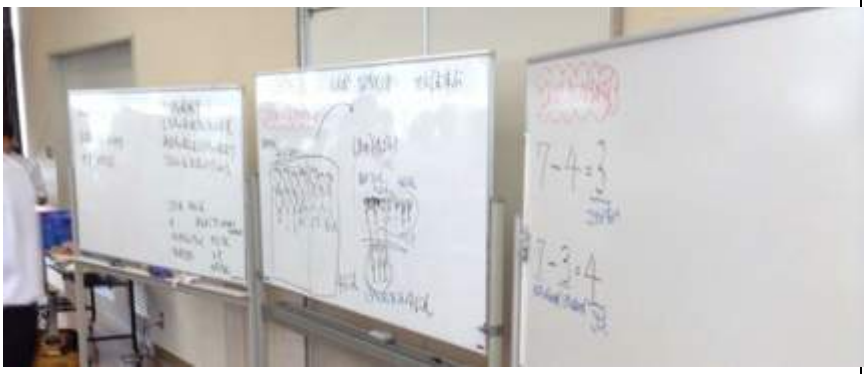
At this point, the teacher asked the class to discuss the picture on the board and their own pages. The partners were to to talk to each other. The students share thoughts and some pointed to the board and then to their notebooks as the partners discussed the diagrams.

The teacher then asks for the students to think of an expression to match the problem. Several students raised their hands to share ideas.

This child erased her original model and modified throughout the class discussion. Below her ruler she wrote her equation and was raising her hand to share her equation idea.

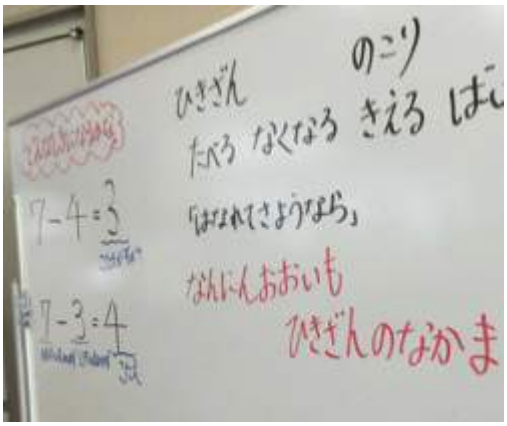
Students shared and the teacher recorded on the board, 7-4=3.
This expression sparked a discussion and one student stated that the expression does not match the story in the problem.

The teacher then asked for another expression and the students came up with 7-3=4.



Referring to the student models on the board, the teacher then asked the class such questions as:

- Where is the 7?
- Where is the 3?
- What is the answer?

		● Where in the picture? ● Is this [expression] okay? From here, the teacher helped the students to make connections between the story, picture and expression and the idea of when or situations we would use subtraction by asking such questions as, “When we look back to the story, where is the subtraction in story?” From here and with the student language, the teacher creates the summary to state that when they use *how many more* can say that it can also mean subtration.
	4.Summary /Consolidation of Knowledge	Strategies to support consolidation, e.g., blackboard writing, class discussion, math journals To summarize the lesson, the teacher highlighted ways the students had used subtraction before and how this situation was a new and different way to use subtraction. On the far right board he had written the final question in red: what kind of equation/expression will it be? The students had determined that the equation would be 7 - 3 = 4.  The teacher reminded the students that they already knew that we used subtraction "to say goodbye" and asked students if they saw that sort of scenario in this story problem. On the board the teacher had written the students' language for known subtraction scenarios in black under the heading "subtraction": remaining, eat, disappear, "poof!," bye bye, separate, goodbye. The students confirmed that this story problem did not include one of these "goodbye" situations. The teacher asked the students again, where is the subtraction in this story? One student came up to the board, who pointed to the story problem and said, if the problem says "how many more" we can call it a subtraction problem. The teacher then restated the student's language and wrote the conclusion on the board in red: "How many more is also a friend of subtraction. He reiterated that although they had already learned that subtraction is used when saying goodbye, today they had learned a new way to used subtraction. He then connected to the introduction, telling the students that the next time they play dodgeball they can figure out for themselves the answer. Then, probably due to time constraints, he asked the students to write their reflections when they returned to the classroom.

What new insights did you gain about mathematics or pedagogy from the debriefing and group discussion of the lesson?

One aspect of the lesson that immediately stood out to us as strong was the way the teacher drew the students into lesson. To illustrate a comparison situation, the teacher shared an application that was familiar and engaging to the students: a game of dodgeball. Rather than just describing the situation, he opened the lesson by projecting a video of the students themselves playing dodgeball. This immediately sparked the students’ interest, giving the problem an authentic purpose and a personal connection for the class.
Additionally, the teacher created an accessible entry into the problem by modeling mathematical thinking aloud, asking students if they could possibly use something they already know to solve this new problem. Throughout the lesson he continued to draw the students into the problem-solving

process by using their own words and ideas on the board, in diagrams and in the language of the conclusion. We felt this helped give the students mathematical authority and nurtured their problem solving identities.

We were also impressed by the way the lesson encouraged mathematical thinking and metacognition among the students. The structure of the lesson, in focusing on just one problem and multiple solution strategies, helped convey that in problem solving it is the understanding that is important, not the answer-getting. To support this conceptual understanding of the problem situation, the teacher used high-level questioning, asking the students to consider how this subtraction situation compared to other subtraction situations they had studied. He also encouraged the students to compare solution methods, asking this students, "can you improve the strategy?" and "where is the improvement?" He frequently referred back to the word problem, asking students, "where is the equation in this problem?" and drawing attention to the connection between the drawings, the equations, and the word problem situation. This could help create a link between concrete representations and more abstract ones, building a conceptual understanding of comparison as a subtraction situation.

At the same time, this lesson also presented questions for us, especially around what is appropriate for this age group. While the opening of the lesson was quite engaging, we saw evidence from the student work and behavior that over the length of the lesson, which was nearly an hour long and entirely seated (except for the few students who came to the board), student engagement dropped significantly. We have some theories about why this might be and what could be explored for improvement. First, we noticed that while the teacher did build the lesson from the students' train of thought, only about 6 or 7 students shared aloud in the lesson and most of those were seated at the front of the classroom. We would like to see how increasing student talk could potentially increase engagement, perhaps through turn-and-talks or by asking more students to speak aloud during the whole group discussion. The length of time students were asked to attend to one conversation focused at the front of the classroom also seemed to not promote the engagement of students of such a young age. Perhaps the lesson period could be broken up into smaller activities, incorporating movement, physical models, or even guided note-taking/drawing. Overall, we were left wondering: at this age level, how do you make sure all students are engaged, participating, and understanding?

Another aspect that left us with questions was the use of board-work with this age group. The teacher mentioned that, having just recently entered school, his students represented a broad range of ability in reading, writing, and drawing. This led us to ask, while the teacher chose to make the board-work a central part of the lesson, how many students were making sense of the board writing? This was complicated by the fact that a good portion of the board work was actually written by students, a practice we saw at very few lessons over the course of our program. We understand the advantage of having students share their own work on the board in building student ownership and agency, but we are concerned about the ways it may have detracted from the effectiveness of the lesson. For example, the time it took for students to copy their work onto the board was time we observed only part of the class attending and participating. And when the drawings were completed, they were not necessarily as clear as they could have been, especially when the teacher modified them as the lesson went on, adding arrows to represent possible "take away" scenarios. In fact, even as adults in the room, some of us struggled to really make sense of the final display of work on the board: the arrows were more confusing than clarifying.

We wondered then, if the use of board writing could be modified to better fit this age range. For example, if the teacher really wanted to use the student's own diagrams on the board, could he have them write their work on sheets of construction paper during independent work and post different diagrams to the board during discussion time? Or could he simply chose to transcribe the student's work himself, making the diagrams larger and clearer? Additionally, to make sure that more students could access the different diagrams that were shared on the board, could he prepare small photocopies of different diagrams ahead of time and distribute these slips of paper to students once

that particular diagram/solution method comes up in discussion? That way students could save an accurate copy of the diagram into their notebooks, perhaps adding their own arrows and notations. Whatever the method, we felt that more needed
to be done to encourage broader access among these very young students to the work that was shared at the board.

What new insights did you gain about how administrators can support teachers to do lesson study?

Administrators play an integral role in promoting lesson study. The practice of having all administrators and teachers present at the research lesson sets the tone. In America, sometimes there is the perception of them (admin) and us (teachers). By having the administration there actively engaged in the process the divide is narrowed. Now both students, teachers, and admin are on the same page working together to improve teaching and learning. Having the administrators lead parts of the post-lesson discussion shows the value of the work the teachers are doing and raises the level of professionalism. Finally, having a Saturday open house in which all teachers and administration from the district would participate further bridges the gap between school sites and again aides in teaching and learning for all.

How does this lesson contribute to our understanding of high-impact practices?

This lesson contributes to our understanding of a high-impact instructional practice in several ways. First, the lesson created much drama in the situation. By showing the importance of creating the drama in the problem, the students were engaged and eager to think about the situation of which team had won the game of dodgeball. We saw this engagement throughout the lesson as the students, even when the board work note writing was taking a long time, were still engaged. Another area the lesson contributed to a high-impact instructional practice is when many, if not all the students had an entry point to solve the problem. There was a range of approaches that they students were using to solve the problem, many of which were discussed in the lesson introduction such as drawing diagrams or pictures, using counters, organizing the diagrams and lining up the team players to compare. When the teacher reviewed the ways they had used in the past, it allowed for the strategies to be fresh in the students' minds, which aided in success. As a high-impact lesson, this one connected the learning for the students as the instructor focused on wrapping up the lesson. As the class was making sense of the mathematical expression, the students kept referring back to the story and the model or diagram on the board to make sure the expression matched and made sense. This process created a deeper learning for the students by connecting all aspects of problem solving.
This group was left wondering after the lesson just how impactful the board work was for the students. Is it a best practice at this age to have the kids write on the board? While it helped with engagement and students having agency, identity, and authority, was it the best use of the class time or developmentally appropriate for children of this age to be expected to to sit and listen for that length of time? This group was wondering if it would be appropriate to introduce a lesson on quick sketching in math, rather than detailed drawings, might have been helpful or have the students bring up their work using an ELMO projector device may have been advantageous.

June 25:University of Yamanashi Attached Elementary School *G6

Group report by:

TEHKIM HONG, CHOY Ban Heng, Rebecca Zisook, Graham Charles

What are the primary lesson goals?

The primary goal for this lesson is to provide opportunities for students to reason that the quotient represents a ratio when the divisor is considered as one whole using diagrams and equations. The aim of this lesson is for students to think about the meaning of fractions by interpreting the meaning of the quotient and fractional remainder in a quotitive division problem with fractional divisor.

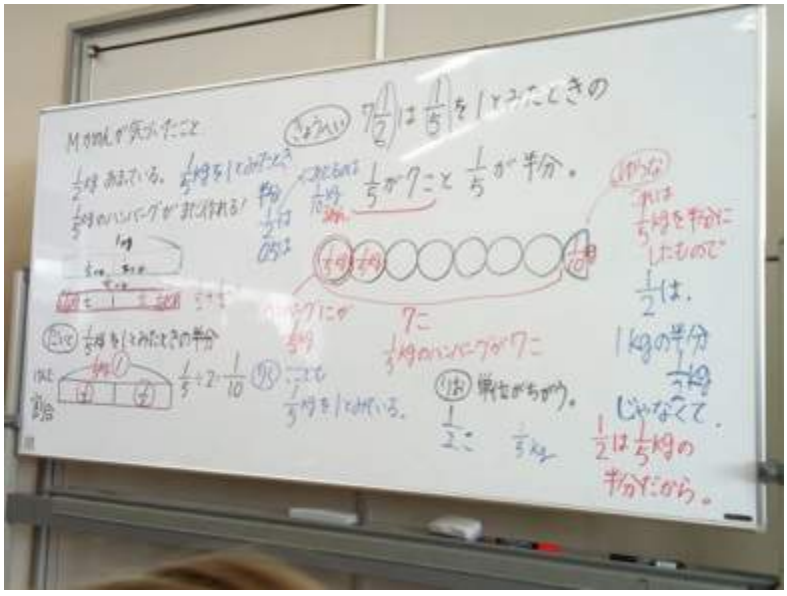
Where is the lesson located within the unit (in relation to previously studied topics and ideas to be studied in the future)?

This is the last lesson of a series of 11 lessons in this unit on fractions. Prior to this lesson, students had learnt about division of fractions: division of proper fraction by a proper fraction, division of a whole number by a fraction, multiplication and division of numbers involving fractions and decimal representations, use of the double number line to solve problems, solving problems involving ratios and seeing them as division by fractions.

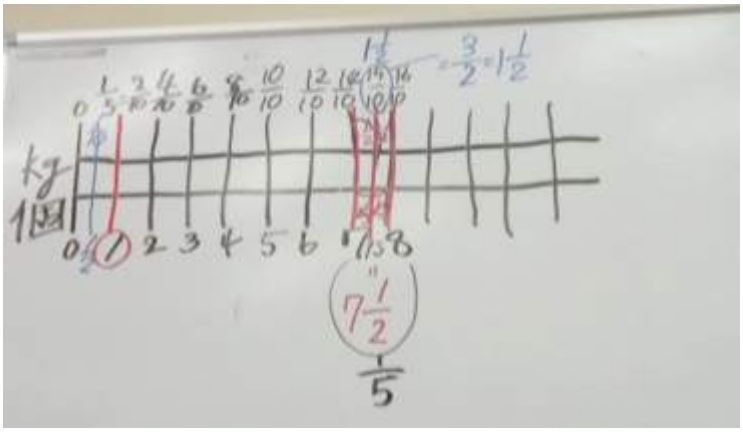
Start &End Time	Lesson Phase	Notes
	1. Introduction, Posing Task	**Strategies to build interest or connect to prior knowledge** -Exact posing of problem, including visuals The teacher opened the lesson with a gesture that made the class laugh: posting a photo of ground beef. This gave the kids a tangible context for the day's problem. She then took a few minutes to establish that ground beef is what you make hamburgers with. She then posted another photo, this time of uncooked hamburger patties. This intro gave students context, preemptively clarified any possible misconceptions that may have arisen around the words "ground beef" and, more importantly for the problem, "patties." She asked, "How many of you have made hamburgers at home?" Students raised their hands. The teacher's launching of the lesson in this way established rapport with the class, which appeared to be evidence of prior community building. The teacher then posed the first problem: We have 1 ½ kg of ground meat. We are going to make ½-kg hamburger patties. How many hamburger patties can we make? Several students remarked, "This is too simple…" As a class, the group decided the equation would be 1 ½ divided by ½. Teacher: Why do we divide? Student: We are splitting 1 ½ kg into ½-kg pieces. Teacher: So we can say this is division. Let's do this together. Teacher wrote notes on board as students guided the solving of the problem. Teacher: So we can make 3 patties. Students: This is way too simple. Teacher: I'm going to change something to make it more challenging. What should I change?

		Students: [unable to catch response] Teacher wrote new problem on board, using 1/5 instead of ½ for size of the patty. Teacher: Is 1/5 more or less than ½? Students: Less Teacher: So what does that mean for the problem? Students: So now we are making smaller patties. Teacher: How many patties can we make? Find the answer in your notebook.  Students applied the calculation skills that would be needed in the day's task to a much simpler problem. Several students remarked, "This is too easy." Our interpretation is that students were able to establish comfort and confidence in the solving of the intro problem, which seemed to serve them in solving the day's task, which seemed to be significantly more challenging because of the fractional part in the quotient. Students were motivated to work on the task because of their confidence, and also because of the increase in challenge, namely the 1/5kg sized patty instead of the 1/2kg patty.
1003 to 1010	2. Independent Problem-Solving	**-Individual, pairs, group, or combination of strategies?** -Experience of diverse learners - Teacher's activities Teacher posed the following problem to students during the independent problem solving phase of the lesson: We have 1⁄2 kg of ground meat. We are going to make 1⁄5-kg hamburger patties. How many hamburger patties can we make? As expected, students used one of two anticipated responses and most of them had no problem working out the quotient and the remainder. However, a number of them had different answers to the word problem and this was also anticipated by the teacher. The figures below show samples of students' responses.  Sample 1: Equation with 7½ as the answer. Here, the student applied the algorithm and obtained 7½ as the answer and expressed the answer to the question as 7½.  Sample 2: Equation with 7 as the answer. Similar to Sample 1, the student applied the division algorithm to obtain the quotient of 7½ but

		expressed the answer to the word problem as 7.  Sample 4: Double Number Line with 7 as the answer. Unlike Sample 3, the student expressed the answer to the question as 7. Sample 3: Double Number Line with 7½ as the answer. The student used the strategy of double number line and worked out the answer of 7½ and expressed the answer to the word problem as 7½ too.   Sample 5: Double Number Line with wrong answer 9 because of a computation error.
	3.Presentation of Students' Thinking, Class Discussion	**Student Thinking / Visuals / Peer Responses /Teacher Responses** Photos to document chronology (use new box for each new student idea presented] The teacher selected a pupil to give their answer 'I can make 7 patties and have ½ Kg left', which was the first suggestion shared. The teacher followed this up with 'Does anybody have a different solution?' This revealed: 7 patties and ½ Kg left over (14 students) 7 patties (10 students) 7 and a half patties (2 students) 7.5 patties (3 students) 8 and a half patties (1 student) Note: The student who gave 8½ as the answer was also the person who gave 9 during individual problem solving. The teacher followed this up, asking if students agreed that ½ Kg is left over.

		The representations shared by 3 students to show their thinking with the whole class on the board were: 1) 2 equivalent bars to highlight the difference between 1/2 of 1Kg and 1/2 of 1/5Kg 2) Seven and a half circles, with 1/5 placed in the whole circles, to highlight that 1/2 of 1/5Kg was left over 3) Double number line, used to support solving (not just representing) the problem  Discussion then followed regarding each possible solution. Student: "Wait, ½ is greater than 1/5." Teacher: Who understands that? Can you repeat it? Student: ½ is greater than 1/5, so if we have ½, we can make more patties. Students realized at that moment that the ½ could not refer to kg of meat. One student asked to come up to the board to draw a diagram. He drew a 1kg bar split into two equal pieces, each labeled "½ Kg." Underneath, he began to draw another bar diagram, but the teacher stopped him. Teacher: What is he going to draw? The student then drew a 1/5kg bar split into two equal parts, and labeled each part "1/2," (not ½ kg, but also not attached to a unit at all). Then the teacher asked if they students understand what this student had drawn. She asked another student to explain. Student: There is ½ of 1/5 kg left. The teacher captured this on the board. And had another student reiterate what the former student had said about the size of the whole being 1/5 kg.

		Then the teacher captured this thinking on the board. 7 ½ means 7 of 1/5 and ½ of 1/5. Next, the teacher asked Teacher: Where do you get the idea of 1/5 as 1? Where do you see that on the board? A student came to the board to explain using the previous bar model drawn. Then a student volunteered that they had another model drawn in their notes. This student came to the board and drew seven circles and one half circle. The teacher had another student come to the board and explain the diagram. This student wrote 1/5 in the first circle and counted the seven circles and said, there are seven of them. The teacher added 1/5 to the rest of the circles in the diagram. Clarifying "did he count this one?" as she pointed to the half circle and the class agreed that he did not. She had another student come to the board to finish the explanation of what as seen in this circle drawing. Then the teacher said: Teacher: does everyone understand? In pairs, tell each other what you understood. At this point a student came to the board and summarize what he had understood, using what was written on the board. Teacher: If you're not quite confident, listen closely. Student: You can't make more patties because this ½ is not ½ kg but ½ patty. It is ½ of 1/5. ½ is a different unit. It's not kg. Student: So Kento's [student who drew first diagram using 1kg split into two equal parts]'s idea is not totally correct. Teacher: Is Kento's diagram incorrect? What is 1? Student: [referring to half circle drawing on board] in the diagram is a 1/10kg Student approached the board and referred to the diagram where 1/5 was represented by a bar and "1/2" was written in each half of the bar. This [pointing to the ½] is also 1/10kg. Teacher: If we consider 1/5kg as one, what corresponds to ½ or 0.5 is 1/10kg. Student approached board to share double number line approach. The student that shared the double number line approach was able to make sense of and solve the problem in a way with the general structure being familiar to others. The students had been practicing use of double number lines in previous lessons. Most students represented the problem using double number lines. The selected student used the double number line to support solving the problem,

		which we understand to be developed with the class at a later stage. When asked, the teacher explained that it was deliberate not to show the double number line approach when reviewing the initial questions to see if students used them with their independent thinking to help solve the problem.  The photo above highlight how the student refined their work from their initial number line in their book to that which was shared with the whole class on the board. The original included an error with 13/10 shown, despite previously adding 2 to the numerators each time, recognising 2/10 as equivalent to 1/5. Whilst the double number line shared was clear to understand, it was not as efficient as it could have been. The student recognised the multiplicative relationship vertically between the top and bottom line. She applied an additive approach to find the solution horizontally on the double number lines. We understand that opportunities to use the more efficient multiplicative approach are shared in future lessons. Working horizontally in a multiplicative way to just show answers to how many patties you can make with the following amounts (in Kg) of mincemeat 2/10, 4/10, 8/10 and 16/10, then reduce to 15/10 reduces the number of calculations, leaving only the need to double numbers, which is much quicker, with simple subtraction to finish. This point is supported by the error originally made in their book. The teacher enabled student responses and representations to lead developments within the lesson. We did not observe any students working using decimals, even though 7.5 was shared as a solution. She may decide to refer to this at another point. This enabled the lesson to stay focused on the key point relating to fractions.
	4.Summary /Conso	Strategies to support consolidation, e.g., blackboard writing, class discussion, math journals.

	lidation of Knowledge	The teachers posed pictures of patties and hamburger to elaborate the context of the problem. After some discussion, the teacher was able set the students ready to connect from the known to the unknown by putting up a task "We have 1⁄2 kg of ground meat. We are going to make 1⁄5-kg hamburger patties. How many hamburger patties can we make? Students were allow time to solve problem on their own. During the discussion and sharing session the teacher was able to put the student's ideas and suggestion systematically. The layout on the board was very systematic. In this lesson, the teacher seemed to have two periods of summary or consolidation. First, she summed up the discussion around whether there were seven and a half hamburgers or seven hamburger patties and one half kilogram. The second summary was around how many kilograms that half patty was actually worth. The teacher use a number of strategies to help consolidate knowledge. In summarizing the understandings the class had come to, the teacher focused discussion around the student generated diagrams on the board. Additionally, the teacher based discussion around student words and comments, supplementing with very few ideas of her own. She artfully chose to capture or discussion student comments that led to her intended objective but barely if ever "told" the students what they needed to know. She also frequently had students summarize the ideas of others instead of doing it herself. All of these strategies were very prominent in the process of summarizing the lesson. The teacher seemed to run out of time for an official summary of the learning. In the lesson plan, it seems the summary would have been "1/2 in 7 ½ did not mean ½ kg leftover. It means ½ (ratio) of 1 hamburger (1/5 kg)." However, no official summary was actually written on the board during the lesson. Instead, towards the end of the lesson the teacher added to student diagrams on the board and the double number line the student had drawn at the end of the lesson. The students were told to reflect in their journals when they returned to class.

What new insights did you gain about mathematics or pedagogy from the debriefing and group discussion of the lesson?

- There is a difference between avoiding over-scaffolding, and leaving students confused and an unproductive way. The teacher's job is to avoid both of these situations, but still to challenge the students at their zone of proximal development.
- We expect a lot of sustained attention from students, with students either listening to peers and teacher, or waiting to speak one at a time, sometimes for 35 to 40 minutes in the discussion portion of a lesson. Is this fair? Is it best practice? How can we avoid student fatigue and maintain student engagement during discussion portion of a lesson? How does this function for students with attention disorders especially? What specific supports are necessary?
- After student answers are identified as being incorrect, it is a powerful practice to move onto the following questions: "Why is this wrong?" "How did I get this wrong answer?" These questions can prompt students to reflect more deeply on their own learning and their own mathematical process.
- The intentional use of pair discussion is important, though the planning for those discussions may not be able to be truly anticipated, because the need for pair

discussions often comes as a result of what the teacher is observing in the moment during a lesson. In this lesson, students shared in order to answer the question, "What did you understand?" This seemed to be a good choice, as it allowed confused students to wrestle with the content together.

- It is important to weave in students' own words for the summary and also to draw out their questions and make their questions explicit within the lesson. Students should be aware of their own questions in order to focus their solving of a problem.

What new insights did you gain about how administrators can support teachers to do lesson study?

- The fact that this lesson was held as part of an open house, on a Saturday, shows a valuing of lesson study as a practice. Giving some amount of reverence to the process validates teacher effort.
- Administrators need to be clued in as instructional leaders. In this way, they will be more equipped to helping the development of a school-wide research theme and in steering the work toward that goal.
- One job of administrators should be making connections to resources that can serve as guides such as knowledgeable others. Administrators should allow planning time for the teaching team.
- Administrators need to cultivate a school culture that supports teacher vulnerability and honest reflection, as opposed to a punitive environment, or opportunities for nonproductive teacher criticism, teacher to teacher

How does this lesson contribute to our understanding of high-impact practices?

This was a very impressive lesson that enable us to understand high-impact practices in a classroom. The lesson was well designed with a purposeful effort to encourage student engagement and successful learning. The teachers started the lesson by posing contextual problem with pictures that aroused the interest of the students during a light session of questions and answers. The teacher did it so skillfully and subtlety that the whole class was engaged and keen to solve the problem of the day.

The teacher did not use complex problem but instead a simple problem that the students thought so, practicing the fundamental teaching of from the known to the unknown or complex. The extension of a simple problem led to a very challenging discussion that kept the students stay engaged. At this level students were engaged in solving the problem of the day by giving the correct answer.

However the climax and the engagement of challenge came during the discussion about the meaning of the '½' in the answer 7½. The teacher intentionally picked various representative examples to be used as subjects for discussion that actually allowed many students to feel good because their solutions were considered as examples. This practice provides recognition for the students' effort and motivate them to sustain learning together with their peers.

During discussion, the teacher facilitated the discussion by posing relevant questions to help students make connections based on their diversity of solutions. It was during this complex processes that mathematical thinking were developed. Students gave different solutions to the key problem with justifications. Through other different examples and counter examples, they were able to make a generalization. In short the teacher had created a situation where students were able to think critically based on a rich problem and make decisions independently with conviction. The

whole process of problem solving had actually demonstrated how mathematical thinking can be developed in a mathematics lesson.

Another point to learn in this lesson was the importance of systematic use of writing board to illustrate students' thinking process. The board recorded students' ideas, presentations and teacher's probe to bridge how the class was learning based on the students' ideas. The records also enable students to reflect on what had happened throughout the learning process.

Our group was impressed that a well-designed lesson with skillful facilitation by the teacher enable students to engage in very successful learning of mathematics content and developed mathematical thinking, which is the core objective of mathematics learning. There was also engagement across differences of views and content understanding that were resolved through peer and teacher's feedbacks as well as through self- reflections.

3 Reflection Journals

Felicity Ames

The Beginning

This experience is one that in many ways is hard to put into words. In a whirlwind beginning to the school year I was approached by my school Principal about a lesson study immersion program to be held in Japan later that year. I was unaware that anything like this existed and at this stage had no idea of the incredible learning I was about to experience. I began the application process; still completely oblivious to just how powerful this experience was going to be in shaping my own philosophy of teaching and learning. Term one quickly rolled into term two; I continued to teach and lesson study began to be introduced into our school as a whole school approach. The teaching team within which I work played a role in implementing this as we had been using lesson study as a professional development tool in the previous two years. As a school we read articles, had presentations, worked through the lesson study process and discussed. At this stage I still did not realise the true power of lesson study and as I now realise, I still held onto some of those misconceptions explained by Fujii (2013).

Some of My Misconceptions

It is only now, as I sit here writing this report that I think my misconceptions around lesson study are unravelling slightly more. This unravelling first began on my second day in Tokyo. As we sat in Tokyo Gakugei University for the very first time I began to be exposed to authentic Japanese lesson study. Two presentations were given, both by Professor Takahashi; Lesson Study in Japan and Teaching through Problem Solving. It was within these presentations where I began to really see the benefits of lesson study and teaching through problem solving. It was these presentations that began to give me the tools to explain to others the importance of lesson study.

Re-teaching and the idea of the 'Perfect Lesson'

On this first day at the University two misconceptions I held were explained in a way that began to make sense to me. I knew previously that these two ideas were misconceptions however I did not understand the reasoning behind them until now. These two misconceptions were the idea of re-teaching the lesson to create the 'perfect lesson'. Each of these misconceptions have been heavily discussed by the teachers I work with and they continue to be discussed now. This immersion program has given me the knowledge and the tools to discuss these misconceptions with understanding and has enabled me to see the reasons behind why these are not important element of lesson study and discuss this with my colleagues. As stated by Fujii (2013, p. 12) one 'problem with re-teaching is that it reinforces the idea that the same lesson plan can be used with different students [and] in this kind of thinking, the students are not an important consideration'. Fujii (2013, p. 12) goes on to say that 'this is in outright opposition to a core value of lesson study'. The lesson study immersion program has allowed me to see first-hand why these misconceptions are important ones to breakdown.

Neriage Phase; Comparison and Discussion

I have been involved in conversations with other educators on a number of occasions regarding the *neriage* (discussion) phase of a research lesson. During these conversations it has been mentioned a number of times that the student discussion at the end of a lesson is not just 'show and tell'. However many times I had been involved in these discussions, it was not until I had seen this *neriage* phase in Japan that I truly realised the importance and structure of this phase. During this

phase the students discuss and compare solutions. Fujii (2016) identifies this as 'the most difficult [phase] for the teachers to deal with'. He goes on to say that 'each correct solution has equal value in terms of getting an answer [yet] the ideas involved may not have equal value'. Fujii (2016) identifies the *neriage* phase as 'when the teacher elicits these ideas and discusses the value of each solution'. I believe the importance of this phase is not yet seen by many teachers within Australia. Since my return from Japan it has been a focus of mine to share the importance and the value of this phase with my colleagues. I am excited about this idea developing within the school I teach at.

It was only by participating within this immersion program and viewing authentic lesson study that I have been able to grapple with these misconceptions and begin to change my thinking. It is only now and through developing knowledge around lesson study from this experience that I am able to identify these misconceptions and explain to others why these are misconceptions around lesson study.

Noteworthy Elements of Lesson Study

Kyouzai Kenkyuu

Kyouzai kenkyuu is 'the careful study of academic content and teaching materials'; an integral part of lesson study as practiced in Japan (Takahashi et al. 2005; Takahashi & Yoshida 2004). The importance of this element of lesson study became apparent to me very quickly as we began to observe the lesson study process. It was evident in the quality of teaching we saw as well as the consistencies we saw across teaching mathematics within Japan. I believe the quality of *kyouzai kenkyuu* plays an incredibly important role within the success of a lesson as well as the lesson study process. This was made clear within a number of lessons we observed where the success of the lesson could clearly be put down to the careful *kyouzai kenkyuu* and planning applied by the teacher.

The Mathematics Textbooks

A number of discussions regarding *kyouzai kenkyuu* also involved discussion on the Japanese textbooks used when teaching mathematics. I found these textbooks incredibly intriguing as we have nothing like them within Australia. There is an abundance of mathematics textbooks produced in Australia; all with slightly different ideas; none of which are as carefully researched and thought out as the ones used within Japan. These textbooks appear to be a powerful teaching and learning tools when used in the correct manner.

Board Work

A critical element within the discussion phase of the lesson is the board work. I was completely fascinated when I first saw this. It was particularly interesting to see the teacher's plan of their board work and then to see it unfold within the classroom with the teacher building upon each of the students' solutions. One particular board was developed in an incredibly impressive manner, containing a combination of mathematical expressions, words and diagrams. This particular teacher also colour coded different shapes being used to solve the problem and was consistent with this throughout the lesson. It was incredibly insightful to watch the creation of these boards within the research lessons and this has been particularly inspiring within my own teaching of mathematics.

The Role of the Teachers

With lesson study being practiced in Japan for over 100 years it is clear that this is an impressive professional development tool for teachers that works. What I particularly like about lesson study and what I think makes it unique from all other forms of professional development available to teachers within Australia is that it is driven by the teachers. The lesson study goals are set by educators within the school; the goals for the lesson by the teacher. The lesson is tailored to the needs of the individual students within a particular grade. It is the most purposeful, meaningful and relevant professional development I have seen and this is because the teacher plays a central role in developing and improving their ability to teach and to help the students they teach to learn.

Authentic Japanese lesson study is powerful and I feel incredibly privileged to have experienced this first hand. This immersion program has completely opened my eyes and mind to many teaching and learning possibilities within education. I am excited to share my experiences of lesson study within Japan with other educators within Australia and to hopefully inspire them and open them up to this exciting approach to teaching and learning. I have met some incredible and knowledgeable people within this program and I would like to thank everyone for sharing a part of their educational world with me.

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Susie Groves

I have visited Japan on numerous occasions over the past 23 years for between a few weeks and a few months and observed many mathematics classes and lesson studies in that time. As with all my visits, I feel that I learned many new things at this IMPULS immersion program.

As always, I was impressed by both the Japanese structured problem-solving lessons with its aim is to teach mathematical content through problem solving, and the focus on mathematics in the post-lesson discussions.

This program highlighted for me many things that I "knew" at one level, but had not really understood before.

Different purposes & types of lesson study

I was surprised to hear about the different purposes for school-based, district-wide and national lesson studies – that each was intended to address issues appropriate to the level. And that, as a result, a school-based research lesson may be about the implementation of some challenging lesson from the textbook, while a district-wide research lesson might be trying to look at some innovative ways to implement the curriculum, such as introducing division through measurement rather than sharing. And at the national level the research lesson might be demonstrating a way to introduce a new area in the curriculum, such as statistics.

Textbooks

Regarding textbooks, I was surprised to hear that when the Tokyo Shoseki textbook series first introduced the "first page of a unit" problem solving activities there was a debate about whether or not this was OK as it suggested a pedagogical approach rather than just provide the curriculum.

The lesson we saw on calculating the volume of an irregular figure that could be decomposed into

rectangular prisms was particularly impressive. Unlike many of the previous lessons we observed, there was a clear mathematical goal and coherence between the goal, the activity and the summary. The teacher also commented that in the next lesson students would learn to calculate volumes where these methods could not necessarily be used. However I was surprised when we were shown the textbook pages related to this lesson and how closely the teacher had followed the textbook. This illustrated the huge support that Japanese teachers receive from their textbooks – of course provided that it is a "good" textbook series (which was also discussed at a somewhat less successful lesson!) It also demonstrated the fact referred to above that school-based lesson study usually has a different purpose from wider lesson study.

For me it also showed the importance of having alignment between curriculum, pedagogy and available resources.

Knowledgeable others

The importance of the "knowledgeable other" in post-lesson discussions was highlighted by Seino sensei's concluding remarks on the rather unsuccessful $48 \div 3$ lesson, where among other things he highlighted the need to specify clear mathematical goals. Many participants discussed with some awe the skill with which Seino sensei critiqued the lesson while providing constructive way in which it (or future lessons) could be improved. Not all knowledgeable others we heard during the program were equally impressive. The role of the knowledgeable other (and the necessity to have a person skilled in this role) is something that is often discussed by people from other countries trying to implement lesson study. Without a growing pool of such people it is difficult to see how lesson study can live up to its full potential in other countries.

Aha moments & highlights

I am singling out just three highlights here, although I would like to include all the sessions run by Akihiko and also Fujii sensei, as well as Tad Watanabe and all the rest of the team.

- Akihiko's advice that if you want the students to talk more you must talk less

- Akihiko's comment about differentiation and the fact that in Western countries this is often synonymous with teachers having different expectations for students rather than the same expectations of the point they will reach at the end of the lesson but having different entry points for students. When I asked him to elaborate, he said that perhaps some students would start at the beginning of a problem, but others might be given part of the solution and continue to the end. This is a very different way to think about differentiation and one I would definitely like to try.

- Seino sensei's concluding remarks – see above

Student explanations

Having first observed mathematics lessons in Japan at PME 17 in Tsukuba in 1993 and having seen many more such lessons on numerous occasions in Japan (and even a few times in Australia), I saw a few changes from previous lessons I had observed.

I am wondering where the apparently new idea of splitting up explanation into tiny atoms so that

more students can "contribute" to the *neriage* phase of the lesson originated. In several lessons we saw the teacher trying to do this to the detriment of students providing coherent explanations of their solution strategies – on one occasion a student who was interrupted in his explanation became quite visibly angry and disengaged from that point onwards. This was further exacerbated in that particular lesson by the lesson rapidly moving between individual work, "spying time" (!), paired work, and groups of four. It was quite frenetic!

By way of contrast, in one Grade 1 lesson the children's names were written on the board to indicate their solution strategies — a process that I have almost always previously observed but one which was missing in some of the lessons we observed. This not only gives students a sense of ownership of the mathematics but also provides a common language with which to refer to different solutions — e.g. "I did it this way because I remembered that yesterday we used Nakano-san's method to do …" (I have frequently witnessed this type of comment in the past). This also highlights yet another issue with the fragmentation of solutions into line by line explanations by different people where it becomes much less of a mathematical activity owned by the students themselves than an exercise in completing a mathematical argument line by line.

I was surprised by the knowledgable other's comment in the post-lesson discussion for another lesson where he commented on the fact that there was no pair-share discussion in the lesson plan — but happy with the teacher's response that he only uses it if he feels it is needed. Again this is a new trend that I am seeing for the first time here. I wonder to what extent the trend towards insisting that as many people as possible contribute to the discussion in EVERY lesson is a result of the other trend of sometimes streaming year levels into different classes for mathematics where the sense of an established community of inquiry is being lost.

It appears to me that in some lessons the mathematical aims are being submerged by the social aims, which actually are not achieved either.

Use of technology

Three of the lessons we observed involved the use of technology. The last time I recall seeing a Japanese lesson that included any use of technology was in the Year 8 *Changing Shape without Changing Area* video from the TIMSS 1995 Video Study, where the teacher used computer animations to illustrate solutions to a geometric problem. [Incidentally, while looking at this lesson again, I noticed that at around the 7-minute mark in the lesson, the teacher said: "And for now I have placed some hint cards up here so people who want to refer to this can refer to it". This seems to be an example of the differentiation strategy discussed above.]

At IMPULS we saw the (experimental) use of individual iPads for Grade 6 students to use in the volume of shapes lesson. In my opinion, this was very good use of technology – its use was intentional and created opportunities that would not otherwise be available to enhance learning, supporting and expanding the prevailing pedagogy rather than disrupting it. However, my opinion was not shared by many of the commentators at the post-lesson discussion who saw it as a distraction and questioned the use of two-dimensional representations of the three-dimensional objects. People were also surprised that the children had access to iPad. It turned out that the whole system being used was part of an experiment funded through some outside inpout.

By way of contrast, in the Year 9 statistics lesson students were totally left to their own devices regarding how to use the laptop computers available and their use did not seem to offer much in the way of enhancing learning.

In the third of the lessons using technology, motion detectors were used to explore the relationship between the slope of a graph and the speed of the person (or object) creating the graph through the use of the motion. In this case the technology was essential for the lesson.

It is not clear to me how much use of technology there is in Japanese school mathematics lessons, but its use seems to vary considerably.

Ways in which university academics and others are involved with schools

At Yamaguchi I was interested in the handout on the whole school research theme and particularly struck by the number of people from outside the school who appear to have been involved in the lesson study process. Close, on-going collaborations between academics and schools is something we try to achieve in Australia, sometimes with limited success.

Overall, attending this IMPULS immersion program was a wonderful experience and there are many things that I will take away from this and try to incorporate in my own practice. Thank you everyone.

Marlon Ebaeguin

The ten days of the IMPULS Lesson Study Immersion Program proved to be a very fruitful and insightful experience for me. I am very grateful to Fujii-sensei and Takahashi-sensei for giving me the opportunity to take part in the program, and to the whole team for their hard work in order to provide us an enjoyable and meaningful experience. I have structured my reflection according to the following themes: Orientation and Pre-lesson discussions, Research lessons, Post-lesson discussion and the knowledgeable other, and Fellowship and the learning community.

Orientation and pre-lesson discussions

An orientation to the program and an introduction to Japanese Lesson Study were given on the first day. This was really important since all participants were coming from different countries and have different levels of experiences with Lesson Study. It was a good opportunity to teach, clarify, and focus on aspects of Japanese Lesson Study that non-Japanese teachers/practitioners/researchers would not know or could easily miss out on. Education is, after all, something very cultural. As Fujii-sensei remarked, there is nothing wrong with having your own interpretation but it is important to see what 'authentic' Japanese Lesson Study is. This view was shared by most participants who are really keen on learning what the 'true' Japanese style is.

Before observing the research lessons, we had pre-lesson discussions courtesy of Takahashi-sensei, Fujii-sensei, and/or Watanabe-sensei. They were meant to prepare us for the research lesson in terms of the context of the lesson, the task, the textbook, etc. This was quite helpful because it allowed us to be more critical with our observations especially on the lesson we were tasked to write a report on.

Research lessons

We were fortunate to have observed a total of seven research lessons. During the orientation we were reminded that it is not usual to have this many research lessons in a month, as schools in Japan would usually have at most once a month. This clarifies the misconception that Lesson Study is done everyday. The variety of the lessons was good but some of them were perceived to be not so successful. In several conversations I had, frustration and disappointment seemed to be a common sentiment which lasted for a couple of days. I do agree that some of the lessons were not in the same level of quality as the others in terms of kyouzaikenkyu or the demonstrating teacher's in-the-moment decisions during the execution of the lesson, and so on. But it could also be that we were still looking at the lesson with non-Japanese eyes or with an outsider's perspective so comments on the number of male/female students answering and the solvability of some of the tasks. Also, even though we had two translators, the language barrier still limited the participants to focus on things that the translators paid attention to. What is very apparent and consistent in all the research lessons though is the pattern for a structured problem solving oriented lesson.

Most of the tasks have big potential for rich discussions with the students. Two lessons stood out for me, the first was the year 7 lesson on graphing at Tokyo Gakugei University-International Secondary School (TGU-ISS) and the year 6 lesson on fractions at the University of Yamanashi attached elementary school. The year 7 lesson on graphing stood out for me not just because my group was assigned to make a report on it but also because it was not a research lesson but a sample of typical lessons in the school. The lesson made use of motion sensors connected to a graphing calculator. The task required the students to replicate the graph provided by the teacher by moving in front of the sensor. The lesson itself was interesting but did have some shortcomings in terms of solvability and clarity of instructions and goals for the lesson. Nonetheless, I think the lesson was a good example of how problem-solving lessons could be done outside of Lesson Study. The year 6 lesson on fraction stood out for me because I was really impressed with how extensive the students' discussions were. The task was about making 1/5 kg patties from 3 ½ kg of mince. Many students would be able to perform the division and have a procedural understanding of the problem and the solution. However, a lot of students would have misconceptions interpreting the answer which is 7 ½. The teacher facilitated the discussion on understanding what the remainder ½ really meant. This lesson was one of the two lessons we observed for a cross-district Lesson Study. I was quite impressed with the number of teachers who attended the cross-district LS. Japanese teachers' valuing of these opportunities for professional learning is really admirable. I think this value/attitude is very important for all teachers to have. For Japan, this is obviously an enabling factor for LS to work quite successfully but in other national contexts, this could be challenge that needs to be considered.

Post-lesson discussions and the knowledgeable other

After each research lesson, we listened to the post-lesson discussion of the teachers with the help of our two translators. Another discussion immediately followed the post-lesson discussion. This time it was for us, the participants, to ask questions with the help of the translators. The teachers, the school, and the team were very kind and considerate to afford us this chance every time. Since school-based LS is intended really for teachers' professional development, it is not usually open to public so having this chance to address the teachers was a good opportunity for us to ask burning questions.

Two things stood out for me: first is the crucial role of the knowledgeable other and second is the teachers' attitude. Having access to good knowledgeable others help make the lesson study more effective by synthesising observations presented in the post-lesson discussion and combine with different ideas to provide a clearer picture of student learning. It is quite a daunting task which is

why I think it is really ideal to have a knowledgeable other working with a particular school for several years. I was particularly impressed with Seino-sensei, the knowledgeable other for the LS at Saiwai Elementary School. He raised critical questions especially on how the curriculum is reflected in the lesson.
The other thing that struck me the most is the attitude of the teachers towards their profession. Teachers' attitudes toward their work and the subject affect students' learning. I am very impressed with Japanese teachers' work ethic. During the post-lesson discussion at Saiwai Elementary School, the demonstrating teacher mentioned that he practised the lesson by himself three times to make sure everything goes smoothly during the actual lesson. Though the lesson did not turn out to be as successful as he had hoped, I admire this teacher's commitment. I think practising a lesson three times to anticipate different scenarios is something you would not expect from non-Japanese teachers. This attitude shows when you teach and helps you gain the trust from your students. In this particular lesson, even though the lesson was not as successful, what was very evident was how the students were giving their best. The students were working hard because they can see that their teacher is working hard.

Fellowship and the learning community

We were lucky and very grateful to have been invited in several nomikais after the LS. Many would think that the nomikai after LS is not really an important part of the LS activity. I believe otherwise. Of course, one purpose for the nomikai is to celebrate the hard work everyone put in for the LS, but I think the more important reason there is to build and strengthen the relationship between everyone involved. One essential feature of JLS is its collaborative nature. Teachers work collaboratively toward a common goal, however, forging personal relationships with colleagues, opportunities for which nomikais provide, in my opinion, further enhances this working relationship.
During the cross-district LS at Yamanashi, I was really impressed by the number of teachers who attended the event. This is a clear manifestation of Japanese teachers' high level of commitment in their profession and professional growth. This shared understanding and valuing, I think, is one critical enabler of LS in Japan which may not easily be found or replicated in a different national context.

Conclusion

The ten days was well spent on the program as it deepened my understanding of and further strengthened my belief in Lesson Study for improving teacher practice. Hearing ideas, opinions, and beliefs of other participants from different countries was very interesting and thought-provoking at times. I hope this program continues to give more teachers and researchers an opportunity to experience and understand authentic Japanese Lesson Study.

Teh Kim Hong

Back home the mathematics teachers have been struggling on how to teach mathematics using higher order thinking. A considerable huge sum of money had been spent by Ministry of Education to engage overseas consultants to propose and promote programs on higher order thinking (HOTs). Currently there are the i-THINK model, habits of mind which are widely promoted in schools to ensure teachers and students at all levels make use of the recommended models and tools during

teaching and learning. I am not very convinced about how the tools can create wonders to develop students thinking when the thinking tools are used as entity instead as an integrated tool during teaching. Such practice did not augur well in delivery good lessons. Recommendations of Edward de Bono about thinking tools were great in developing critical thinking. However I am also not absolutely sure how I apply convincingly in teaching and learning of mathematics.

And I finally experienced and convincingly believed the mathematics teaching and learning in Japan are the models to emulate while attending IMPULS program.

I have been using some of the videos circulated on Japanese lesson study to learn about teaching mathematics through problem solving and also about lesson study. However the impact of watching videos are not comparable to the personal immersion to witness the actual lessons in the class. I was very fortunate to witness seven research lessons that convinced me that mathematics teaching approaches back at home need to be modify for improvement of quality teaching and student learning. Teaching mathematics through problem solving is a very effective approach to develop mathematical thinking and obviously the related higher order thinking skills (HOTs)

In retrospection, during the whole period of IMPULS program, I did not hear of any deliberation of higher order thinking skills in any occasion but ironically all mathematics teaching exhibited the promotion and development of mathematical thinking which are actually the HOTs that my local schools are yearning to achieve.

In my observations, I learned that the flow of a lesson usually started off with elements of prior knowledge such as a problem discussed in an earlier lesson before proceeding to one particular new core problem. Students were given time to work on the problem individually followed by thorough discussion and investigation among fellow classmates facilitated by the teacher. The discussion really stretched the children's cognitive ability to achieve the lesson objectives in relation to mathematical contents and thinking. At the end of the lesson, the class teacher helped to consolidate the lesson by asking the students to make conclusion of their learning and ended with writing a brief reflection. The practice of writing journal or reflection in every lesson was new to me especially being introduced to students at a very early stage, even at grade one. Such good practice compelled students to think and make a summary of what they have learned. This particular step enhanced the evaluative thoughts of students after an almost hour long lesson.

I noticed that all the teachers that demonstrated the research lesson handled the writing board work excellently as what I saw in videos. The layout of the writing are typical and only essential facts were added such as the problem, the tasks, selected student's work for discussion, conclusions and further problems to try. I was told by a Japanese teacher that managing good banshu is the fundamental skill every teacher should acquire. That was indeed very impressive.

The ability of teachers to handle discussion after students had tried the given tasks varied. However during my few sessions of observations, teachers generally were able to lead and guide the discussion through thoughts provoking questions. Students were given the lead role to explain their suggestions and provide justification related to the given problem. The fellow classmates were quick to object when ideas were not agreeable. There was a very positive form of communication occur through active participation of oral, written, even diagrams and pictures expressions to convey views among students. That was a real time sample lesson that show case what was meant by student-centred learning and engaging the students. The teachers did not provide cue words or ideas but all students put on the thinking hats and constructed the ideas or concepts that was to be learned for the day. Generally students were challenged mentally when learning mathematics. During one of the observation sessions, there was a point I screamed in my heart that why did not

the teacher gave a clue to guide students see a particular point to smoothen the flow of lesson instead of letting the students went on with many suggestions and ideas. The teacher was very patient to probe, getting more views from the students, fine tuning their views and finally the class fixed the key point of the learning in that lesson. I understood then what it meant by challenging the children's thinking through that lesson.

Text books played a very significant role in mathematics teaching in Japan. Initially I was taken aback wondering why teachers follow so strictly to contents in the text books. I finally discovered that the content in the text books has been stringently scrutinized by mathematics experts and educators. Topics in the content are tightly link to promote relational understanding among topics. This could be the reason teachers follow text book content very closely and as the key means for reference. Through this mode all children will receive quite similar standard of delivery from teachers. Back home school children are provided with free allocated text books approved by Ministry of Education. However the quality of text books varied and teachers often resort to different reference books to pick teaching materials that are more current yet conforming to the national curriculum.

My first encounter in Japan was another surprise to learn that Japanese do not repeat a lesson as second cycle of a lesson study. There were some fundamental steps that I have previously followed in lesson study such as forming LS groups among in-service teacher, crafting research team, plan a lesson, conduct the research lesson, then the post lesson discussion, finally revise the lesson to be carried out again in 2nd cycle and in some cases had done even a third cycle. Although the practice outside Japan was different from my present encounters, however there were common findings where teachers agreed they acquired new experiences such as increased knowledge of instructions, increased ability to observe students, improve collaborative work and they are mindful of goal setting in lesson preparations.

I am glad to learn some new features based on the input given during this programme. The samples of collaborative lesson research write out are very useful guide for our future work on LS. The lesson plan has been prepared with coherence to the goals of the unit, and elaboration of the unit with a detail scope and sequence. The expanded details about the lesson to be taught allow observers to understand the flow of lesson and also provide justification the choices of the teacher in carrying out the lesson as planned.

In my opinion, the procedure to prepare this particular collaborative lesson has in fact enhance the knowledge of teachers in lesson preparation with respect to the content of the curriculum. This idea would be a positive step to help teachers improve their knowledge in lesson preparation. Based on my personal experience, I notice many teachers do not actually delve very deeply and holistically into the mathematics curriculum they use. Often school teachers deal quite specifically only to a particular grade they teach. They may not be familiar with the scope of curriculum if it is beyond the scope of the grade involved. This lack of continuity in understanding the whole curriculum used will hinder the teachers in delivering effective classroom practices when making choices to identify learning content, teaching materials and strategies.

The enthusiasm and commitment of Japanese teachers in lesson study was commendable. The head teacher concerned also show a very important supporting role to encourage school based lesson study. All the teachers in the school planned a common time relief to give way for lesson study. I presume this is only possible when the head teacher supports it. This is definitely a new aspect that I need to pick up and share with our local schools. The idea that lesson study is a mechanism to improve classroom practices of every teacher and for professional development need to be disseminated. There is a rampant wrong perception about lesson study as a way to show case school

performance is not appropriate. Wrong perceptions and inappropriate practices about lesson study could be one of the reasons for the low sustainability of lesson study in our local context. Other than this, it is also a great challenge for teachers to find common time to meet and engage in discussion of issues, lesson planning and to carry out the research lesson. Repeating the planning and teaching of a taught lesson could be bothersome and uninteresting when it stretched to 3 cycles. This practice could be a hindrance than an encouragement as like treading in a spot for too long. There are many obstacles encountered when doing lesson study in our local schools. However seeing the cohesiveness of teaching staff and administrator, coupled with collaborative and cooperative work shown during the school visits, I still carry with hopes that the practice of lesson study can be improved and sustain for the betterment of our student learning.

My experience and learning about mathematics teaching and lesson study in Japan provide me a new perspective in these two areas. Although there are a lot of short comings in implementing lesson study, it still remains popular to be introduced for teachers to enhance their professional knowledge and skills. The collaborative learning platform will provide a positive impact on teachers in terms of increased knowledge of subject matters, instruction for promoting mathematical thinking through problem solving and sensitive to students learning needs.

Sui Lin Goei

On a national level I am one of the leading initiators developing the Lesson Study model on a practical implementation level specifically geared towards differentiated teaching and inclusive teaching within classrooms. I am leading a team of researchers who are studying the effect of Lesson Study on differentiation (Tijmen Schipper), teacher discourse in Lesson Study meetings (Tirza Bosma), the student voice within Lesson Study (Madeleine Vreeburg), the use of lesson plans (Jos Alkemade), and Lesson Study as a boundary crossing object (Evelien Geffen). We base our Lesson Study model on the work of Peter Dudley and colleagues in the UK; specifically we have borrowed the concept of so-called 'case-pupils' and have integrated this concept in our Lesson Study cycles. Together with a number of representatives we have written a Dutch article on Lesson Study which was published in our leading Dutch teacher educator journal in December 2015. Furthermore, we have published a Dutch Handbook Lesson Study for practitioners with dr. Siebrich de Vries from the University of Groningen and dr. Nellie Verhoef from the University of Twente. The book was launched at our first Dutch Lesson Study conference on 10 May, 2016 with more than 150+ people attending.

I coach Lesson Study teams as a researcher-facilitator, these are mostly mathematics teams, because of my former experience in research in mathematics in primary education (psychodiagnostic work on math difficulties and dyscalculia and the effect of math clinical interviews on children. My goal to join the IMPULS programme was to gain more insight in the focus on learning processes and activities of the pupils themselves, and how participating teachers can gather proof on the learning processes and activities they have anticipated beforehand (1). And how based on this they can redesign their lessons and activities (2). Also I wished to know more on the rationale and culture from a Japanese point of view (3). Ethnicity and culture are critical components when 'translating' the Lesson Study model to a European state of mind, how can I as a researcher-facilitator develop an 'inside-out' model that prizes the perspective of those in the

community (4). These experiences all would have to lead to the overarching goal of honing the Lesson Study model I/we have developed for practitioners further in the Netherlands. Together with my co-participants from the Netherlands we aim to write an article on our experiences as to disseminate what we have learned.

With these experiences, expectations and anticipation I went into the Lesson Study Immersion Programme of the IMPULS project of dr. Takahashi and his colleagues. Looking back it has been an impressive, tremendous, and breathtaking experience in participating in authentic Lesson Study within its Japanese context. The ten days were a caleidscope of impressions that have taken place. From the immersion in authentic live Lesson Study research lessons to the intensity with which we have been engaging in observing and discussing, from the chatting with like-minded colleagues from all over the world to the meeting with dr. Takahashi, dr. Watanabe, dr. Fuji and their crew of zealous masterstudents (for whom no is not an answer), from visiting the huge city of Tokyo with its many distinctive burroughs to the amazing food experiences everywhere, from sleep overs on tatami's, singing karoake, and to soaking in an onset. A foodie myself I found the Japanese food besides of course Lesson Study a highlight, I have discovered different herbs, textures and tastes.

But let's talk about my reflections on what I have experienced in the Lesson Study Immersion Programme. I am reflecting this from the perspective of an instructional psychologist and a child psychologist, I think I am the only of all participants who is not a mathematics educator.
The organisation of the programme was well thought out, and I found it pleasant there were clear expectations on what was expected from us and what the organisers would like to get out of this Immersion Program. In effect, Takahashi told us in his opening speech on the first day that they wanted to evaluate mathematics teaching and learning in Japan via authentic Lesson Study through the eyes of non-Japanese participants. Writing this, I think I would like to ask them their reflections too on their participation in the programme and also their reflections on our feedback and reflections.
Overall, the programme was very very interesting with a number of themes to chew on whilst thinking about how am I going to braid in the lessons I have learned here into the model of Lesson Study we are developing and honing in the Netherlands. I have experience with efforts in making a professional development model contextually and culturally fit to the local site, context, and venue. This is a challenging adventure, since the components which have arisen out of the narrative of authentic Lesson Study do not necessarily espouse or align with 'western' and/or Dutch values. On top of that, the components of authentic Lesson Study have become 'lost in translation' as Takahashi vehemently articulated. And I agree with this. For integrity and fidelity purposes it is necessary to implement the model as it was intended, however with insight progressing a rethinking of the Lesson Study model towards Collaborative Lesson Research would coin the authentic components better.

Again, I noticed the importance of observing and discussing, but now in a way which for me was very insightful. I am trained and registered child psychologist and used to diagnose math problems and math disorders. I liked the formative part of observing and discussing and how this blends in with assessment as learning, both for pupils and particpating teachers in a Lesson Study.
I still do have questions about this: how do they frame the observations, which are the observation cue points, when do they decide there is evidence, etcera.

Also the meticulously planning of a task and the tasksequence were important elements to think about in the lesson plans. It struck me how profound on the one hand the lesson is prepared, designed and reflected on, and on the other hand how the problem solving strategies were made explicit and anticipated on. I am still not sure how this works, creating struggle for the children, like a kind of cognitive dissonance process, and in this way paving a way via inquiry based learning

to problem solving and constructing new knowledge. I would say that the team of teachers needs to study or research the problem solving strategies of their pupils first via short math dialogues or small think aloud sessions, and based on this decide which strategy is adequate, not so adequate or not adequate, and then decide on a carefully selected sequence of task types and strategies.

As said the programme of the immersion into Japanese Lesson Study was well thought out, translated lesson plans were available, and pre-discussion meets were arranged to prepare us for the live research lessons in the schools, after the live research lessons we could attend the post-lesson discussions of the teacher teams of the schools, and afterwards we had our own post-lesson discussions. The (translated) lessson plans, the way the live-research lessons are delivered and the structure of the post-lesson discussions of the teachers in the schools reflect how the whole teacher community deals with developing good lessons with a very focused time-on-task behavior taking the opportunity to learn very serious for their own professional identity as a teacher, but most of all for their communal professional identity.

However, I was surprised how during our own post-lesson discussions how thin the desriptions and narrations of my participants were, they described the behavior of teachers and students on a behavioral level, and do not seem able to clarify this on a teacher behavior tier with regards to a theory of improvement, neither can they tie in (meta)cognitive processes or constructive cognitive behavior the children show. Furthermore, remarks on the treatment or intervention part are in terms of what could have been done; participants are ample able to look from an outside-inside perspective. I have noticed this before in the coaching teachers in Lesson Study teams in the Netherlands, and have tried to get them a level further: how do you really 'see' that learning has taken place, how do you make the learning processes and activities visible? And how do you anticipate these learning processes and activities of your learners, so you can actually zoom in on their educational and instructional needs?

My final reflections can be summarized as follows:

- Treatment integrity and fidelity of the Japanese Lesson Study for mathematics teaching and learning is high;
- Engagement and on task behavior is purposeful for both teachers and students;
- The problem solving logic is a systemic framework for Japanese mathematics Lesson Study;
- Opportunities to learn are designed carefully to create the likelihood that children will internalize this problem solving logic;
- There is a delibarate choice for teacher-student interaction: positive correlation between classroom management and learning outcomes;
- Use of board work as advance and visual organisers that enhance modeling representations;
- The knowledge-able other as a purposeful professional development intervention to tie the observations and discussions of the team of teachers to overarching goals in the school and/or (national) curriculum.
- Purposeful collaborate efforts of the whole school community to work on learning values and learning behavior of both teachers and pupils.

I could detect a few more specific (instructional) interventions which I will summarize here:

- Modeling the thinking behavior via scaffolding thinking aloud and thinking of the children *(teacher behavior);*
- Asking pupils questions for assessment for learning and assessment as learning by questions, such as: what is the improvement in the sequence of strategies (*strategy development*);
- Drawing upon several gestalt representations as a leverage for development of modeling (*math modeling*);

- Teacher stimulates *efficacy and competency beliefs* with regards to mathematical thinking and development by asking questions like - are you sure/unsure – and asking their accountability within small structures.

I would like to thank the coordinators of the IMPULS Lesson Study Immersion Program for inviting me, I have learned hugely from this opportunity. I would like to thank and applaud them for giving the world the common language of authentic Japanase Lesson Study for mathematics learning and teaching that hopefully will develop in a transcultural language throughout the educational world for professonial teacher learning. I compare this process with 'translanguaging' which in language teaching and learning is described as ´the ability of multilingual speakers to shuttle between languages and to treat the diverse languages that form their repertoire as an integrated system' (Canagarajah, 2011, p. 401). It is my wish that within the Lesson Study community we can shuttle between the many Lesson Study languages spoken in Asia, the US, Australia, and in Europe and form an integrated repertoire in our aim to prize each student we cater for.

Gerrit Roorda

Before beginning my reflection on what I have learned during the IMPULS Immersion Program 2016, I would like to express my gratitude to the entire IMPULS staff and the graduate students. Thanks for the amazing 10 days in Japan, for your hospitality, and for this unique opportunity to examine authentic Japanese Lesson Study in mathematics classrooms.

I will structure my reflections around some major components of the Lesson Study process. For each component I shall describe what I learned about Japanese Lesson study and which aspects could be used in my own country. I will reflect on the lesson plan, external resources, live observations and problem solving.

The Lesson Plan

The lesson plans in the Immersion Program were detailed, and contained information about goals, connections with prior knowledge, relations to assessment standards, the planning of the lesson, expected solutions and about the blackboard writing plan. I suppose it is time-consuming to prepare a lesson in such detail. Sometimes the lesson plan was nearly a 'filmscript', with 'scripted questions and predicted answers'. I was impressed by the hard work and effort done by the Japanese teacher. I was also impressed by the board writing plans of the Japanese Lesson plans. Having the entire lesson with all the student work displayed on the black board, was good for promoting conversations and it provides an excellent overview of the lesson.

My LS-experience in my country is that teachers find it difficult to prepare a detailed lesson plan, because it takes a lot of time. I think we can stimulate teachers to improve the quality of the lesson plans by convincing them of the advantages and the importance of a detailed lesson plan.

External resources

In my country many secondary school teachers work alone, in their own classroom. It is really important to work together, to discuss an exchange ideas, in one central aspect of teaching: ' teaching a lesson' . A group of teachers is responsible for the lesson, so Lesson Study is not about evaluating a teacher, but on learning together.

It became clear to me that studying other textbooks, research articles , and especially the comments of the knowledgeable other can bring discussions to a higher level. I experienced that the knowledgeable other can give different perspectives, and a deeper reflection on the research lesson. The knowledgeable other at one school , a mathematics education professor, showed the importance and the difficulty of the theme ' curved shapes' . In his comments he took into account outcomes from a national test and he did suggestions to improve the lesson.
In the Netherlands this role can be difficult because it can be difficult to find someone who has enough authority in the eyes of the secondary school math teachers. Furthermore, the lesson plans should be ready about a week before the research lesson; my experience is that teachers find it difficult to write an extended lesson plan and to finish it on time.
I think the knowledge other in my country should not take the role as if 'he or she has the knowledge', but more a role as a external source of reflections.

Live observations
During the Immersion Program I 'observed' several lessons by video. One of those lessons was on the volume of a special shape, a rectangular prism. In my opinion the lesson went very well, the teacher could ' follow the script' and the students found exactly the expected solutions. The teachers recorded the solutions of the students on an ipad-screen, so the teacher got a quick overview of the drawings. But in the post-lesson discussion I was surprised to hear 'live-observers' mentioning several mistakes and misconceptions of students. Also the explanation why so many children choose for a specific solution was given by the live-observers. Although I learned much from looking at the live-video stream, I missed much of what happened in the classroom, especially in the 'mind' and in the notebooks of the children.
I think it happens in many countries that Lesson Study research lesson are not live-observed, but only observed by video. Therefore my suggestion would be that LS only should be called LS when there is ' live-observation' . Another point that I learned during the post-lesson discussion was a nice example of collecting ' data' from the notebooks which give an insight in the thinking of many students. It seemed the class was split up in several observation-area's, so the observing teachers know much of what happened in classroom. During the post-lesson discussion they substantiate their claims by factual observation. I was impressed by the focused post-lesson discussion based on participants' observation.

Problem solving
Most lessons in the Immersion Program were centered on a single meaningful mathematical problem, were the students do not know a method for solving the task. It fits well with my own philosophy of mathematics education, but for me it was very useful to experience how problem solving was supported in Japanese mathematics lessons. The focus of the lessons is not on the 'answer' to the problem, but on discovering different methods for solving a task and to deepen the understanding of a concept. I think this really influences the attitude of Japanese students to problems: in my experience they are encouraged to become independent mathematical thinkers. I think this kind of problem solving lessons can also be implemented in my country. To achieve such problem solving goals, I think the classroom culture in many math-classroom should change from 'answer-centered' to 'mathematical thinking'. I was also impressed by the discussions on details of the problems, such as small changes to numbers in the task can lead to identify typical misconceptions of students.

Closing
I think the Lesson Study process can provide teachers in the Netherlands with opportunities to improve teaching and learning. Such opportunities are (1) Collaborate with colleagues on topics that are challenging for teaching and learning; (2) learn from external resources such as, colleagues, other textbooks, articles, knowledgeable others;

(3) Create a classroom culture were problems are central and were students are engaged in the problem solving process; (4) be a teacher who is also a learner.
Takahashi mentioned in the opening session some essential aspects of the Lesson Study process:

- Well planned lesson plan with clear hypothesis
- Live lesson observations with various participants
- Focused post-lesson discussion based on participants' observation

I think in the Netherlands we should look for ways to further implement these essential aspects of Lesson Study in our own culture. The IMPULS program, the growing amount of articles about Japanese Lesson Study and the enthusiasm and efforts of all the IMPULS team members were a very enriching experience. I look forward to using everything I have learnt in Japan in continuing my work on Lesson Study, together with colleagues in the Netherlands, Siebrich de Vries, Sui Lin Goei, Nellie Verhoef.

Cristina Morais

This experience in 2016 IMPULS Immersion Program was very intense and extremely valuable in different perspectives, so I will try to summarize what were the key ideas for me regarding teaching and learning in Japan and Japanese Lesson Study.

Teaching and learning in Japan

The first aspect that I want to emphasize is the way that teachers think about students' learning. One word that kept being repeated throughout the program's days was "struggle" which I think that defines one main aspect in mathematics' lesson.
Mondai kaiketsu gakushu lessons (teaching through problem-solving) are central in mathematics' Japanese lessons. As we have talked, about 70% of mathematics' lessons are through problem solving. It is also important to highlight that the focus or the goal of such lessons is not to solve the problem but the learning that can occur or be promoted by solving the problem. Thus, what is important in problem solving is the process, not the result.
The research lessons that we observed were all mondai kaiketsu gakushu and all were organized into four main moments: introduction posing task (*hatsumon*); independent problem-solving; whole class discussion (*neriage*); and summing up (*matome*). Regarding these four moments, I want to focus some aspects that caught my attention.
As I could observe in most research lessons, in hatsumon the teacher gave some hints to guide his/her students, posing a similar but easier question to guide students' attention to a particular point. Only after this, the problem was posed to all students.
During the program, I kept thinking about these hints and their role. On one hand, it is a moment where aspects approached in mathematics lessons are called upon, to promote the establishment of connections among different ideas. On the other hand, I wonder to what extent are these hints really necessary and how they can confine students' work in the problem posed after the hints.
In the independent problem-solving moment, the teacher carefully observes students strategies, try to understand them and start to select which ones to call for discussion with the whole class. This aspect stresses the importance to allow students time and space to think, to struggle with the problem, mainly without teacher's guidance.
In matome, the ideas are reviewed and the teacher focus students' attention to new ideas discussed in the lesson. I have observed that it is also given time for students to reflect upon the lesson, even though in most lessons observed there wasn't enough time for all students to write their own reflections. I found very interesting that this reflection could highlight not only mathematical ideas,

but any aspect that students feel that were important (e.g. the reflection can be about learning with peers, the confidence felt when solving the problem,…).
Teachers seem to have a clear perspective of these different moments and about what their roles should be in the different phases.

One aspect that I want to point out is how Japanese teachers approach the different achievement levels in the classroom: instead of thinking about different tasks for "different students", the teachers consider that the problem should have the same goal for every student, however it could have different "entry points", depending on each student. I consider this very important because it shifts the perspective of "for different students, different tasks" to a perspective of embracing differences and, together, reaching the same goal (which emphasize the role that each student have in learning together, within the classroom).
Another aspect that I feel I have to include in this reflection is the learning environment in Japanese classrooms: what I thought it would be like and how it actually is. Before arriving to Japan, I thought the classroom environment would be serious and very silent. I also had an idea of Japanese teachers as also very serious and strict. But I couldn't be more wrong. As soon as we enter a Japanese school and classroom, we are embraced by a joyful environment, where "kids are kids". Students talk and laugh with each other as well as with the teacher. I could feel that classroom norms were solidly established, as students seem to understand when was time to talk and when silence was needed to work, without any particular indication from the teacher.
Students seem very aware of their own responsibility in school and in their own learning process. This is also reflected on the autonomy given to students as they go to school by themselves since Grade 1, they are responsible for different tasks at school like serving lunch to their colleagues, … I believe a good word for all these would be "empowering" students. An example of this empowerment could be seen in Yamanashi, at Ryuo Elementary School, where we were welcome not only by the school principal but also by the students' representative.

In every school we visit, the teachers' room had the same layout: the teachers' desks were grouped by Grades, to promote and facilitate group work. I think this idea, that seem to be generalized to all schools, reflects that teachers really work in a collaborative way.

Teachers also seem to be very conscious of the need of their own professional development and appear to be very engaged in improving their practices. In the first day of the IMPULS Program, Professor Takahashi explained to us that the practice of Japanese teachers could be categorized into one of three levels:

- Level 1 – Teachers tell students about the basics, valuing the practice of procedures and not comprehension;
- Level 2 – Teachers can explain meanings and reasons of the basics;
- Level 3 – Teachers can provide students with opportunities to understand the basic ideas and support their learning so that they became independent learners. Teachers in this level can design tasks to support such learning.

Teachers are seen as "novice teachers" until they have at least 10 years of practice, which again reflects the importance given to the need to continue to discuss and improve teachers' practices.

In the lessons observed, none of the teachers had used the school manual, which is different from most of the Portuguese lessons. Even though the Japanese school manuals are comprised by very well thought tasks, even improved by Lesson Study, the teachers seem to have a need to adapt the tasks to their own students and make decisions related to the task exploration in the classroom.

Finally, the last aspect I want to stress is the board writing in the lessons. It was impressive to see all the thought and preparation of the board writing: chalk colors used to highlight different aspects, figures that could be magnetically placed in the board to support the writing,... I thought it was very interesting that the use of the board was so carefully planned that in the end of the lesson we could see all four moments of problem-solving. I believe it helps students to see the connections among lesson's mathematical ideas.

Japanese Lesson Study (*jugyokenkyu*)

I want to start by mention how embedded Lesson Study is in the Japanese teachers' practice. Even in their schedules there is a time assigned for Lesson Study work. It was very interesting to see, as well as inspiring, the way that all teachers in the school engage in Lesson Study. Not only the teacher in charge of the lesson and the planning team are deeply involved, but their colleagues as well. There seems to be no constraints for the teachers to open their classroom door to their colleagues (or even to all IMPULS Program participants).

Focusing Lesson Study process itself, we weren't able to have access to what happened in the preparation phase, but we could understand the work made to make the lesson plan and we could observe both the research lessons and the post-lesson discussions.

Lesson planning

Reading the lesson plan, we could understand the amount and depth of the work done by the teachers. This lesson plan was much more thought that what we could call as a usual plan for a lesson. It starts with establishing a "common ground" among teacher: *kyozai-kenkyu.* This is an extremely important stage of planning, as it is when teachers establish common language among them and engage in a deep study about the lesson topic, also studying curriculum materials. In my understanding, it is a moment that research in mathematics education comes into action and reaches the classrooms.

It is also very important to stress teachers' anticipation of students' strategies and difficulties concerning the task. It is this anticipation that will help the teacher to make decisions in the lesson, when he/she tries to understand students' strategies and select which ones are brought to discussion.

Research lesson

I was surprised to see that not only the planning team observed the lesson, but also all teachers do it too. Teachers really knew what to observe in the lesson: they kept notes from teacher and students sayings and took photographs to document whole class moments and students' strategies.

Not only the lesson itself was interesting for me to observe but also it was very important for me to understand how the teachers involved observed the lessons. It was very helpful to see these, in order to guide my own observations of lessons but also how to help my colleagues how to do so.

Post-lesson discussion

Again, the level of depth of the lesson discussion was remarkable. I found the strategy to write in post-its positive comments and comments to help to improve the lesson very helpful has a way to organize the discussion among teachers. Teachers talked about their own practice and the practice of others in a very transparent way, without any constraints, which I believe in other contexts, like in my own country, is not so easy to do. We need to distinguish between teacher as a person and teacher's actions, which can be further improved in order to also improve students' learning.

To summarize the discussion, the role of the Knowledgeable Other was impressive. Only in this program I could really see and understand how important it is. He focus the attention of teachers to aspects that maybe passed unnoticed either in the planning stage or in the post-lesson discussion. As I understood, he is the one that complements the work of the teachers with the research work in the field, as well as with a thoughtful perspective of curriculum materials, that sometimes is not that clear for teachers.

Unfortunately, we don't have the opportunity to know "what will happen next" in each school we went to. I wonder how the post-lesson discussion main ideas to change or improved will impact or be incorporated in future lessons. However, one thing that became very clear is that it's not usual to re-teach the same lesson, as sometimes is perceived in some literature. It is not the goal of Lesson Study to re-teach the lessons, as it is a process of learning for teachers that can only happen when the lesson don't go as planned, and not a process to create perfect lessons or perfect tasks, because there is no such thing.

Lastly, I have to recall the Open House that we had opportunity to go. It was surprising to see how

the all school community get involved in Lesson Study, which again shows that teachers recognize the impact of this process of professional development in their practices. In my opinion, organizing an Open House to share with teachers from my country a glance of Lesson Study "in action" could be a way to help them to see how powerful Lesson Study could be.

I have to finish by saying Thank You one more time and that I'm extremely grateful to have been part of IMPULS Program. It was a unique experience that provided me with skills that I plan to further develop in order to bring Lesson Study into my own context.

Marisa Quaresma

Fist of all I would like to start my reflective journal to say thank you for this opportunity. As a researcher working with lesson study in my country I have read a lot about this topic but it is always different to immerge in the real context where it is original, working and learning with the experts who wrote papers that I have read. Since we were seeing mathematics teaching and learning in Japan trough Japanese Lesson Study, it is difficult for me reflect about these separately. So, maybe the most part of my reflections will be a combinations of both.

Trying to start my reflections about mathematics teaching and learning in Japan I have to underline the problem solving lessons. In Portugal, when we speak about problem solving, usually, we focus more the nature of task than the working moments during the lesson. In Portugal we have traditional classroom very widespread and a few years ago over here we are trying to move for another perspective (exploratory approach which is close to problem solving). However, change everything (lesson structure and tasks) could be hard for these teachers and we decided to start to distinguish simple exercises from problems. In Japan I saw teachers using very well the structure of the lesson, introduction, individual/pairs work and all class discussion. However, I am not sure if all task could be classified as a problem. So, my reflection is, what can be the more productive entry point for introduce problem solving approach in our schools? Can we separate this two aspects of problem solving?

As I mentioned before, in general, teachers in Japan use this lesson structure very well and is important to reflect about the three moments of the lesson. About introduction I have two mains comments /reflections. Teachers in Japan do this well, it was very interesting to see teachers and students engaging into the task since the beginning of the lesson and teachers challenging students to understand what it supposed to do. Something that I appreciated in this introduction too was "the solution can appear in this phase" because it does not matter so much, what is really important is the process. However, as I wrote in my daily reflections, I am a little bit concerned with the "hints". Sometimes I feel "hints" closing the tasks and conditioning the solutions of the students. I know, teachers are no much time and maybe they can not spend much time with students out of the task, but sometimes students need to struggle with their difficulties and have time to discover their own way.

During the independent work was interesting see students engaged in the task firstly individually. Would be good students understand the task first for themselves and in this way they can participate more deeply in the work with the colleagues. Was quite surprised for me see students walking around the classroom and talking a lot with each other during de work in pairs/groups as I thought in Japan students could not do so much noise inside de classroom. At the same time was interesting see students respecting teachers and stop the conversation when teachers talk.

For me, collective discussion is the most powerful phase in a lesson and we could see this in the

Japanese Classroom. Teachers and students discussed a lot of different resolutions and tried to add meaning for each expression, number and picture. This is a big support for students learning. Also they use a lot of manipulative and visual material that can support students to understand complex concepts. For sure this is possible also because teachers develop this classroom environment in which students try to figure out many different resolutions and make an effort to understand and discuss each other's resolutions.
Finally, I would like to highlight how the teachers in Japan use textbooks. They select the tasks of textbooks but then adapt them to their own goals and students suggesting the task in lesson differently than appear in the textbook, however, take advantage of many of the suggestions and resolutions presented in the textbook. It is very good! Unfortunately, in Portugal teachers use textbooks indiscriminately and simply send the students open the textbook on page they want and follow step by step what is there. Can you imagine what would happen if the students had access to resolution while have to solve the task? It is not very productive and problems become rapidly simple exercises.
Now it is time to change the course of my reflections for the Japanese Lesson Study. I will focus my reflection on the aspects I found differently in relation to the readings I have been doing. First I emphasize the fact that there is no re-teaching in Japan and the reasons that underlie it. Of course, there is not a perfect lesson plan and "revision does not necessarily improve the lesson" particularly, because "we are working with different group of students with different mathematical experiences" and needs. In fact, I think that this issue has a strong influence in the post lesson reflection. As we have seen in Japan, the group can discuss ways to help those students to continue their learning process. I found this very interesting perspective to discuss not only the teaching and learning in that lesson but also to think about how to help the teacher and the students in the future. In this sense, I need to also outline the important role of knowledgeable that more than criticize or comment on the performance of teachers, help them to realize a more general and transversely way (along the various grades) to help students to better understand the topic discussed in this lesson and if the lesson has not gone well, try to help the teachers to understand where they made mistakes and why. This is a very difficult role to play and on which we should also think when we try to implement the LS in different countries on a large scale. I think it will be necessary not only to spread LS to schools and teachers in schools, it is also necessary for us to discuss the role of mathematics educators in this process.
Once again I would like to thank you for this opportunity not only to learn with you and with your experience but also the opportunity to interrogate myself and what I thought I knew and to reflect deeply on my learning and knowledge.

Ban Heng Choy

unpacking the black box: teacher noticing and learning from lesson study

Learning from Lesson Study is not trivial: it requires adopting different lenses to investigate mathematics content, student thinking and pedagogy in their specific educational contexts. Although Lesson Study has been adopted and adapted in different countries, its impact on improving teaching and learning is limited by implementations characterised by following the superficial features of the Lesson Study cycle. The IMPULS programme not only opened my eyes to see the Japanese teachers' careful investigation of curriculum materials, lesson observations and

students' work, but also highlight the importance of a hidden skill of teaching: mathematics teacher noticing. In this reflection piece, I will briefly introduce the connections between Lesson Study and noticing, before highlighting some implications for future work on Lesson Study in Singapore.

Learning from Lesson Study and Noticing

Many countries have adopted or adapted the Japanese Lesson Study for their own contexts. However, the impact on learning has been limited. Participating in Lesson Study is not a sufficient condition for professional learning. As Fernandez, Cannon, and Chokshi (2003) highlight, teachers need to put on three critical lenses when they attempt to learn from Lesson Study. Based on my own observations of Lesson Study sessions in Singapore, teachers often do not put on these three lenses—the researcher's lens, the student's lens and the curriculum developer's lens—when they inquire into their teaching practice (Choy, 2013, 2014a, 2014b). To learn from Lesson Study, it is crucial for teachers to investigate specific problems of teaching and learning (researcher's lens) by examining students' mathematical thinking (student's lens) and the mathematics embedded in the curriculum materials (curriculum developer's lens). However, doing this inquiry work can be very challenging (Fernandez et al., 2003), and teachers often fail to implement the essential features of Lesson Study in their adapted implementation of Lesson Study (Takahashi & McDougal, 2016). It remains unclear how teachers can maximise their professional learning. Hence, it is important to examine the "black box" of learning from teacher inquiry practices such as Lesson Study.

One important aspect of teacher expertise that is gaining traction in mathematics education research is mathematics teacher noticing—what teachers attend to, how they interpret what they see and how they decide to respond based on their analysis of the observations (Jacobs, Lamb, & Philipp, 2010). Mason (2002) sees noticing as a shift of attention, and as he (2003) puts it, learning from professional development always involves teachers noticing mathematical details that they might have missed in the past:

Every approach [to professional development] that has some influence boils down in the end to individuals becoming sensitised to notice more and different details, so that it is possible to surmount habits and to act freshly and responsively (Mason, 2003, p. 286).

Even though noticing is highly consequential for improving teaching (Schoenfeld, 2011), not all noticing is productive. The crux lies in what teachers attend to, and how they think about instructional events (Ball, 2011). For example, it can be difficult for teachers to notice the mathematical features of learning tasks (Star, Lynch, & Perova, 2011; Vondrová & Žalská, 2013), or teachers may be distracted by noticing features that are not useful for enhancing mathematical thinking (Ball, 2011; Star & Strickland, 2008). These problems in teacher inquiry are common to many Lesson Study implementations, and it appears that mathematics teacher noticing may help to unpack part of the black box of learning from Lesson Study. In the next section, I present some snapshots of teacher noticing during a research lesson at Saiwai Elementary School as part of the IMPULS programme before I highlight implications for Singapore Lesson Study practitioners.

snapshots of teacher noticing at Saiwai Elementary

During the third day, we observed a lesson at Saiwai Elementary School. The objective of the lesson was to build on students' knowledge of working out division problems such as 36 / 3 in order to work on questions such as 48 / 3. This lesson preceded the lesson on the division algorithm (long division). The teacher followed the lesson plan closely at the beginning. However, some students rattled off the answer "16" when he introduced the problem of 48/3. Instead of hearing them out, the teacher followed the lesson plan closely although many students were "confused" about what he wanted them to do. The teacher tried to recover the deviation from the original plan when his expected answers did not appear, but with little success. The following vignettes are snapshots of what teachers noticed during the post-lesson discussion.

Noticing the mathematics

During the post-lesson discussion, the teachers were prompted by the Knowledgeable Other to consider the key point or new idea that students were supposed to learn. In particular, the Knowledgeable Other reminded the teachers on how the Grade 3 textbook addressed 36/3 in two different ways: First, use and extend the multiplication table.
3 x 10 = 30
3 x 11 = 33
3 x 12 = 36 …
The second strategy involves splitting the 36 into its tens and ones. So, 36 = 30 + 6. So, 30/3 = 10 and 6/3 = 2. Therefore, 36/3 = 12. But what makes it illuminating was how the knowledgeable other referred to the practice questions and highlighted the key difference between 36/3 and 48/3. He highlighted that the practice questions involved dividends that are made up of tens and ones that are divisible by the divisor, e.g., 33 / 3 and 48 / 4 etc. The teachers' attention was shifted when they noticed that 48 / 3 was chosen because 40 and 8 are not exactly divisibly 3. The teachers realized the key point of the lesson was to split the number 48 into two numbers that are divisible by the divisor, which could lead to the long division algorithm.

Noticing students' thinking

Besides noticing the mathematics, the teachers were very specific when they described the observations during post-lesson discussions. For example, the teachers noted that one of the students tried to split 48 into 40 and 8 during the lesson. It appeared that the researcher teacher may have realized that this failed strategy could potentially lead to a mathematically productive discussion because he asked the student to present his solution. However, he stopped short of linking the "mistake" to the intended objective of the lesson.
During the post-lesson discussion, the teachers also examined another critical incident in which one of the students offered to break 48 into 30 and 18, and used a pictorial representation to show what she meant. They noted that the teacher decided to move away from her approach and invited another student to describe his method: Since 12/3 = 4, and there are 4 sets of 12 to make up 48, therefore the answer is 4 x 4 = 16. This was despite the fact that the research teacher was aware of the mathematics potential of her approach. Although the teacher wanted to address the 48 = 30 + 18 approach, he did not because he ran out of time. Here, we see that the teacher did not notice productively as a result of his attention on his intended approach. Even though he might have realized that the girl's solution could have led to a fruitful discussion, he did not respond in-the-moment to orchestrate the discussion in class.

Implications for Singapore Lesson Study implementation

As highlighted above, mathematics teacher noticing or shifting teachers' attention to relevant mathematical details is necessary for teachers when learning from the processes of Lesson Study. In this final section, I suggest some implications for the implementation of Lesson Study in Singapore.

Focus on *kyouzai kenkyu*

The study of the textbook goes beyond looking at the problem posed, but also how the problem is posed and positioned to provide opportunities for student to engage in mathematical processes when learning new concepts. This may involve building up the concepts from students' prior knowledge and considering the choice of numbers to facilitate students' learning. In addition, it is not sufficient to consider the research lesson task in isolation. Instead, it is critical for teachers to examine the scope and sequencing of the subtopics. Furthermore, examining what and why students may be confused about the concept is necessary for teachers to design good problem solving tasks for use during the lesson. Unfortunately, these aspects of lesson planning are missing in many Singapore schools. Most of the time, teachers pay little attention to the mathematical concepts, the underlying cognitive difficulties and how the design of tasks can be tweaked to

support students' learning. They instead focus on the research lesson and think about "innovative" or "interesting" lesson ideas, which may not target students' learning difficulties. Very often, teachers neither think about the numbers used in the task nor consider the developmental sequence of the concept through the lessons before and after the research lesson. To encourage teachers to notice these features, it may necessary to provide an explicit focus and position pedagogical reasoning as the key mechanisms by which teachers make their instructional decisions. I think that using students' confusion about a concept, as a starting point in task design may be useful. How this can be done would need further research.

Focus on orchestrating discussions

As described by Takahashi during the IMPULS programme, the notion of using problem solving to teach new mathematical concepts is an essential component of mathematics teaching in Japan. Although both Japan and Singapore place problem solving as the heart of the mathematics curriculum, the two countries differ in their approaches. The Japanese teachers use problems to teach concepts without teaching students the concepts. By carefully designing a problem task, they are able to engage students in problem solving using their prior knowledge. Students' sharing of their informal solutions then becomes the platform for teachers to connect the responses to teach the new mathematical idea. In contrast, in Singapore classrooms, we often start by teaching the procedures or techniques or concepts before engaging students to apply these learned techniques to solve problems. The Japanese problem solving approach is a radical shift from our usual teaching approach. However, such an approach really engages students in mathematical sense making and provides the learning experiences necessary to develop students' mathematical competencies. To initiate such a shift in our teaching style, there is a need to think about how our Ministry of Education's recent emphasis on learning experiences may dovetail into the goal of teaching through problem solving.

Focus on mathematically productive reflections

Finally, orchestrating mathematically productive post-lesson discussions is an important platform for learning from Lesson Study. There are at least three issues relating to the quality of post-lesson discussions held in Singapore. Firstly, teachers may gloss over some of the learning points or say something vague or too generic to give a "feel-good" mood during post-lesson discussions. Secondly, teachers may be too critical of the teacher by commenting on what the teacher did not do well instead of focusing on whether the instructional approach and materials were appropriate. In either case, the discussion would not have fulfilled its purpose of investigating problems of practice. To enhance the quality of post-lesson discussions in Singapore, there is a need to consider how teachers can be supported in noticing the mathematically productive details. Lastly, the role of the Knowledgeable Other is not explicit and well understood in Singapore. The episode at Saiwai Elementary School highlighted the importance of Knowledgeable Other. In Singapore, I think there is a need to nurture leaders who can be a knowledgeable other. Perhaps, we need to consider how Lesson Study in Singapore can be brought to a higher level by examining the current practices surrounding the Knowledgeable Other.

Concluding Remarks

In summary, I highlight the critical role that mathematics teacher noticing plays in Lesson Study and suggest three key areas for Lesson Study practitioners in Singapore to consider for future implementation. The role of teacher noticing in Lesson Study will be a fruitful area for further investigation in the future. Overall, I think the IMPULS programme has opened my eyes to understand better how Japanese teachers notice during Lesson Study.

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Stéphane Clivaz

Introduction: Participating in IMPULS program

Participating in many research lessons and discussions in open and committed schools, with teachers and educators from all over the world, helped by wonderful graduate students and guided by so knowledgeable *sensei* was, of course, a privilege. For me, as math teacher, as a teacher educator, as a lesson study facilitator, as a researcher on lesson study and as a head of lesson study's team, it was an extraordinary opportunity to observe various levels of activity and to learn about students learning, about math teaching, about lesson study practice and about non-Japanese

people experiencing authentic Japanese 授業研究. Among all the things I've learned, I will reflect here first about three similarities/differences between the teaching/learning of mathematics I know in the French-speaking part of Switzerland and what I observed in Japan. I will then briefly reflect about the link between teaching through problem-solving and lesson study. The last section will consider two adaptations made in Lausanne from the original Japanese lesson study and consider the next step for our Lausanne lesson studies.

Teaching and learning mathematics in Japan

Three points were especially gripping for me when observing and discussing the research lessons: the presenting of the problem phase (*hatsumon*), the comparing and discussing phase (*neriage*), and the blackboard planning and writing (*bansho*).

Hatsumon

The first part of the research lessons we observed, and the first part of problem-solving lessons in Japan, is the posing of the problem. The goal of the lesson is not solving the problem but building new knowledge by solving the problem. Therefore, the problem and its presentation were generally carefully designed to direct the student in some way to use a strategy making use of the expected knowledge, but without directly giving him this knowledge. This *hatsumon* phase was especially interesting for me because on the one hand, it was very similar to the conception of the *French didactique des mathématiques* (Clivaz, 2015) where the knowledge is constructed by the students in interaction with the problem, but on the other hand, it was different in a subtle way. In some Japanese lessons we observed, the students used the knowledge because of the *hatsumon* (for example because they were first given a simple example with division of fraction and were told the problem of the day was the same kind of problem) and not because of the problem itself. Whereas, in *didactique des mathématiques* (DDM) the intended knowledge should be the most adequate way to solve the problem, given the previous knowledge of the students. Even more, in DDM, the knowledge can be modeled in a fundamental situation, or a family of situations, who will preserve and even give back the sense of this knowledge (Brousseau, 1998).

Let's take an example. In one of the lessons (see *Let's think about division of fractions* in this report), the problem was:

We have 1½ kg of ground meat. We are going to make 1/5 kg hamburger patties. How many hamburger patties can we make?

The most elegant way for the students to solve the problem would certainly have been to use Euclidian division by transforming the weights into grams:

1500 ÷ 200 = 7 remainder 100. We can make 7 patties and have 100 grams left.

By doing that, the students would have avoided the division by a fraction, avoided the interpretation of the remainder, and would have solved the problem in a quick and easy way. They would also have learned to choose the best knowledge to solve a problem. But they would not have learned anything about division of fractions. In the lesson we observed, no student used this strategy and all students used division by a fraction (because of *hatsumon*). They learned about division by fractions, but probably not about choosing the best tool to solve a problem. Here is my genuine interrogation today about this example: is there a better problem for these students to make them work with division of fractions because *the problem itself* asks them to do so? And if the answer is yes, would the new lesson be considered a better Japanese problem-solving lesson or is it not important that the necessity to use an intended knowledge comes from the problem rather than from the *hatsumon* in Japan? This question can be generalized, since in some other lessons we observed, the *hatsumon* played the same influence on the independent solving phase and in the *neriage*.

Neriage

The main part of the research lessons we observed, and the main part of problem-solving lessons in

Japan, is the dialogue between the teacher and the students about the different solution methods and the comparison and discussion of those different solution methods (Fujii, 2016). For me, this part of the lesson was extraordinarily impressive in many ways. This was the case in many lessons we observed, but I will discuss as a generic example the lesson about *area of curved figures* (see this report).

First of all, during the discussion, the teacher really used the students' idea and didn't seem to make his own ideas pass using the students for that. The students were aware of that and they contributed to the discussion with passion and reflection. They gave me the impression they were aware that they were contributing not only to the solution of the problem, but also to the construction of the knowledge. This dialogue was carefully designed and used a very efficient pattern:

1. Teacher calls a student to present her/his solution and tells the student the way he wants her/him to present the solution.
2. Student stands up and, stay at her/his desk and explain her/his strategy. The teacher writes the student's solution on the board.
3. The teacher asks a second student to come to the board and to explain the strategy to the class, sometimes using a different format (see picture below: math sentence, graphic, text, …).
4. The teacher reformulates the explanation and uses different colors to frame key elements and to show the parallels between the different expressions of the solution. He also writes some key comments in a speech bubble (see picture below).

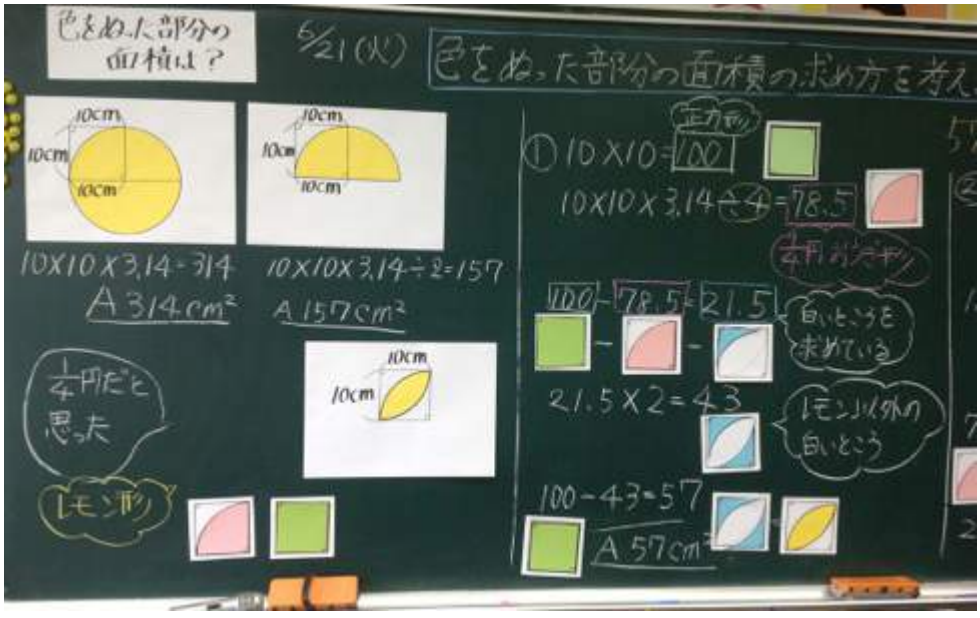
Secondly, the discussion was not only about finding one solution to the problem, but about various ways to do it. All ways used the intended knowledge, and the students were equally interested in all new methods. The teacher also made the students reflect on the similarities and differences of the methods, made students compare them, sometimes label them and would ask the students to use them for new similar problems.

Thirdly, even if the discussion seemed to follow the students' ideas, the order of the ideas was following the teacher's plan. This was made possible by the teacher's observations and noting during the independent problem-solving phase. In my view, this apparent paradox was a great representation of teaching through problem-solving, probably from a DDM as well as from a Japanese point of view: the knowledge was constructed collectively by the students, based on their individual research and brought together in a very coherent way by the teacher.

This paradox was made possible by the art of using the blackboard, the *bansho*.

Bansho

After already speaking about the *bansho,* a picture is worth a thousand words…



This picture shows a part of the blackboard and illustrates the elements I have just mentioned. It is to be noted, that the actual black board was similar (with small adaptations)

to the board writing plan of the lesson plan. In fact, the teacher told us he had rehearsed the lesson by writing on the board and that he had a picture of it.

When I looked at this picture, I was impressed with how it materialized the solution of the apparent paradox between careful preparation and following students' ideas.

Link between teaching through problem-solving and lesson study

IMPULS program presented us both with lesson study and with teaching mathematics through problem-solving in Japan. The two are at different levels (teacher professional process / teaching), and the program promoted both of these elements. The above was seen in lectures, in the discussions among participants and in the reflections I am sharing here. The two levels were linked, tangled and sometimes mixed. Since I was reflecting about this connection in my own research, this program gave me a lot more to think about and I will continue with my new learning. At this point, I would advocate studying this link and its limits, in Japan and abroad, and to make it more explicit. In my point of view, this would make promotion for both, lesson study (in math, but not only, with a problem-solving point of view, but not only) and teaching through problem-solving in lesson study, even more efficient outside Japan.

IMPULS and Lausanne lesson study

During the IMPULS program, I felt, as a representative for the Lausanne lesson study groups I would bring the knowledge I have obtained in Japan back to my own program. I tried to learn and to retain the maximum of elements to bring them back to my colleagues, to the teachers, the student teachers and, ultimately, to the students. Back in Switzerland, I'd like to mention here two adaptations we made compared to the lesson study process I observed during IMPULS program and look forward to the next steps.

Some adaptations

One surprise I had, as many other participants, was that, in Japan, the study of the curriculum (*kyozai-kenkyu*) and the planning phase was essentially done by the teacher alone. In Lausanne, as in many western lesson study groups, this phase is collective and I consider it as necessary. The teachers are not used to doing this work alone. Further, it would probably be very difficult for them to do it alone. Moreover, when facilitating lesson study groups in theses phases and even more when analyzing the conversations occurring then, I can show how much teacher learning occurs during these collaborative moments. Sometimes, the collaboration is so strong, that the lesson can be taught in several classes and we decide who will teach the lesson during the last planning session. This allows a de-personalization of teaching. During the research lesson, the teacher represents every teacher and every teacher feels observing her/himself teaching in an *avatar effect* (Clivaz, 2016).

Another difference with Lausanne lesson study is that Japanese lesson study teams usually do not reteach the lesson (Fujii, 2014). Fujii-sensei insisted about that and that helped me to clarify the reason we often reteach the lesson in our Lausanne groups and how we can avoid the dangers pointed out by Fujii. The question we ask in the group we facilitate in Lausanne is: "will we learn more about teaching this subject if we work again on this lesson and teach it in another class?". The goal is never to reach a perfect lesson, the new lesson is always different from the first one and we never did more than one "second lesson". I observed that the teacher learned a lot by changing key elements in the lesson and noticing the difference in student learning these changes brought.

And now…

Other differences I observed will probably lead us to some changes in our Lausanne lesson studies. Better differentiating between facilitator and knowledgeable other (Takahashi, 2014; Takahashi & McDougal, 2016), working with whole school(s) rather than with several groups in several schools to reach the kind of effect I observed in Japan and in Chicago (Takahashi & McDougal, 2016)… We will also try to have Swiss teachers attending IMPULS (or IMPULS like) programs. This is another point I would like to write another whole reflective journal on: the wonderful contributions the teachers from all over the world in this program gave. The mix of cultures and educational professionals around lesson study was that powerful that I would love some Swiss teachers to experiment. Thank you so much IMPULS people, thank you so much all IMPULS participants!

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Brigid Brown

Before participating in the IMPULSE program, I already had a strong sense that lesson study could be a powerful tool for improving teaching and learning. I had experienced the intense research and planning aspect of a lesson study cycle as a student teacher and seen the value of diving deeply into a particular lesson or topic. This past year, when we implemented school wide lesson study at our small, public elementary school in Oakland, California, I saw how different lesson study is from so many districtled professional development experiences, which tend towards

an input format. I could see that lesson study had the potential to really improve teaching practice. However, after participating in the IMPULSE program I now know not just that lesson study can be effective, I now know HOW it can be effective. Through our experiences and studies I've learned what aspects of the teaching, organization, administrative support, and mindset of Japanese lesson study can make it an effective tool for improving learning and teaching, not just in Japan but in my own teaching context.

One of the most interesting aspects of the IMPULSE program was getting to see and experience Japanese curriculum and a Japanese way of teaching math, especially teaching through problemsolving.

First of all, the differences between American and Japanese elementary math curriculums are huge. Whereas American curriculum provides more materials than could possibly be covered in a year, the Japanese curriculum covers far fewer topics. Over the course of the conference, we saw evidence that Japanese math teaching, instead of aiming for broad "coverage" of material, focuses on fewer topics and on a carefully selected progression of questions within a unit. In problemsolving lessons, students are encouraged to adopt a problemsolving stance and reason mathematically about new challenges, making sense of them through exploration as well as thoughtfullyled class discussions that seek to reach consensus on successful strategies. Students forge connections with prior learning, not through reminders from teachers, but by thinking, "what do I already know that might help me solve this new problem?" The students help create the learning, and in so doing, they seem to take responsibility for their work.

Japanese teachers have an invaluable resource in planning this focused math work, in that they have curriculum that is thoroughly evaluated and does not overload teachers with materials. This difference in curriculum and course of study has previously seemed like a daunting, at times insurmountable challenge in implementing problemsolving based instruction in our school. However, now that I have a better understanding of what problem solving means in this context, it actually seems more accessible. In our first year implementing lesson study at our school, many teachers got stuck, wondering, "but what is a worthy problem for a problembased lesson?" Many of the examples we had seen seemed disconnected from our everyday lessons (and from the standards we are required to cover). Through my experience at IMPULSE we clarified that a "problem" is simply a question for which the students do not yet know how to find an answer. It does not have to be an elaborate task or a special puzzle, it could be as simple as an new type of equation. The defining element is that the responsibility is on the students to figure out on their own how to solve it. Last year I had heard Dr. Takahashi say that American teachers do too much of the work for their students... Now I see what he meant! Far too much time in the curriculum we have been using at our school is dedicated to students practicing over and over strategies that teachers have already given them. Such exercises are not entirely absent from a Japanese math unit, but they take up less time and tend to come after students themselves have a chance to explore strategies.

As I prepare to return to my school for the new school year, I have a better idea of how to incorporate this learning about Japanesestyle math instruction in our context. Immediately it will be important to develop a shared definition of what makes a "problem" as opposed to exercises or tasks. In our school, the curriculum we use is not perfectly aligned with a problemsolving approach. However, this year we will be implementing a new curriculum, which at least is much less dense than our previous curriculum. My hope is that this will ease the workload on teachers and give them a little more space in their schedules for problembased lessons. Additionally, I hope that through lesson study we can begin identifying as a staff the places within our curriculum where problembased lessons could replace ones based more on teacher explanations.

Here we can apply a more nuanced understanding of the research aspect of the lesson study routine. As we saw many planning teams do in Japan, we can make a study not just of our own curriculum, attempting to discover and understand the logic of its progression of lessons, but we can also study other curriculums in comparison to our own. By looking at, say, the translation of Japanese textbooks, we can compare which types of questions were included and excluded in

different curriculum and make better informed decisions about where to focus our students' efforts. In particular, I believe it would be especially powerful to choose one strand of our math standards as a school, such a numbers in base ten or subtraction, and study that concept as it develops across the grades from kindergarten to fifth. As our professors pointed out, this curriculum research is one of the ways that the impact of one particular lesson study cycle can extend beyond the individual lesson or grade.

This touches on what was perhaps the most significant aspect of lesson study that I got to see during the IMPULSE program: the way in which the process of lesson study opens lines of communication and collaboration between educators at all levels within the school or the education system. This collaboration might take place within a school, across a district, between teachers and academics, and go so far as to be in dialogue with curriculum writers and educational policy makers. However, for my context, the schoolbased lesson study provides the most applicable example. In the very first lesson we observed at IMPULSE, I was amazed by the level of inclusion of all staff members in the lesson study process. The research lesson was taught in one classroom, but the entire school staff participated in the observation and postlesson discussion. Other students in the school were dismissed after lunch to free up teachers and staff. The benefit of this whole school approach is that there's a continuity in the schoolwide learning: the whole staff builds a body of shared lesson study experiences and a point that arises in one research lesson can be applied or examined in subsequent lesson study cycles. This keeps the research moving forward even though only one class teaches a lesson at a time.

During our first attempt at lesson study in our school this past year, we organized our research lessons in a much more isolated way. For various reasons, we felt it important that the research lesson occur during the normal student school day. However, as a result we felt constrained by timing and the need to get substitute coverage in order for teachers to be free to plan or observe a lesson. As in the schoolwide research lessons we observed on IMPULSE, we planned lessons in small teams of teachers, but when it came time to teach the research lesson, no teachers from outside the planning team were able to participate in the lesson observation and discussion: only administrators or guests from outside the school participated.

And, as opposed to what we saw in Japanese schools, other staff members, such as resource teachers or interventionists, were not included in our observations and discussions. As such, our research was very disjointed, which was made worse by the fact that we didn't have a good method for sharing our learnings with our coworkers.

Next year, I'd like to apply some of what we saw in Japan when scheduling the research lesson cycles. I think it would be extremely important for the whole school staff to be available to observe and participate in discussion important enough that we could rearrange our schedule to hold research lessons during our weekly professional development time after school lets out.
This would require a lot of effort and commitment from our administration to garner the support and involvement of both families and staff. We would need to send home permission slips for students to stay after school on days when their class was doing a research lesson. We would also need to facilitate the attendance of additional staff members. However, after seeing the ways the various school members contributed during the discussions we observed, I think it could really deepen the learning experience.

For example, following one of the lessons we observed, some very useful comments were shared by a resource teacher in attendance, who happened to work with two of the students in the classroom. She was able to offer insights from her work with these students in an intervention group, and gave specific suggestions for how to account for their individual learning challenges. Especially since our school has recently expanded our special education inclusion program, this sort of sharing of perspectives among different professionals on staff could be incredibly useful in helping us meet the needs of all our students. More generally, having all teachers present for each discussion could help our teachers benefit from each other's work and

I believe move our practice forward more effectively and quickly. Each cycle would have the

potential to move not just the planning team, but the whole school forward in their research. Additionally, by being present for lessons in different grade levels, teachers could have an opportunity to deepen their pedagogical content knowledge as they observe lessons that come in earlier or later grades.

Part of what was so inspiring about participating in the IMPULSE program was getting to see not just how lesson study works in Japan, but how it works in Japan in concert with every other aspect of the country's educational system, teacher preparation system, academia, and the culture as a whole. Being able to observe firsthand the Japanese education system at work gave me a deeper understanding and appreciation for how these values and practices intersect in lesson study. In particular, I was able to get a sense of the growth mindset that surrounds the practice of teaching in Japan. Teachers are expected to grow and refine their practice over many years and lesson study figures into this growth from teacher preparation onwards. The emphasis on growth of skills, as opposed to the natural ability or talent that is emphasized in the United States, seemed to facilitate the teachers being willing to engage in the daunting process of teaching a public lesson. When we asked teachers if they were nervous about teaching in front of so many observers, they tended to respond that they felt somewhat nervous, but that they were eager to get the help to improve. One teacher even said, "I really need the help because I am a novice teacherI've only been teaching eight years!" I was amazed at the comment, since having taught for eight years would put him among the ranks of the most experienced teachers at my school! Unfortunately we have to struggle to retain teachers past their first few years of teaching in our highneeds, underfunded urban school district.

In the context of our educational system and the way that teaching is viewed in our country, adopting this kind of mindset can seem like a long stretch. Nationwide, too many teachers are evaluated based on the results of highstakes yearly standardized tests for students beginning in grade three and the failures of our education system are too often blamed on "ineffective" teachers. Inherent in that label is a fixed mindset: teachers are either effective or ineffective. As such, it can be difficult for teachers to take the risk of exposing their practice to so many observers. Even at our school, where we have a strong collaborative school culture and a lot of trust, we found ourselves getting bogged down in anxiety of creating a "perfect" lesson and "performing" in front of so many people. It would take a very deep shift in mindset to counteract an education system steeped in a fixed mindset; to shift to the one that lesson study demands, where a collaborative team of educators can, as Dr. Takahashi put it, judge the teaching not the teacher.

Over the course of my time with IMPULSE, my colleagues and I gradually gained a deeper understanding of many of the different aspects of Japanese lesson study and how it fits in the larger educational system of Japan. So many aspects are so different from the way things are done in the United States, especially when it comes to the view of the profession and the growth mindset with respect to teacher professional development. At some points in the process, the differences could seem overwhelming and we would find ourselves saying, "that wouldn't work in my context because..." However, by the end of the program I felt like I had concrete ideas for how to strengthen our schoolwide lesson study in our particular context. Using the Japanese teaching we saw as an example, we should first clarify our staff's understanding of what is a problemsolving lesson and how and where it can fit in our school's curriculum and standards.

Secondly, we should reorganize the structure of our lesson study in such a way as to involve all of the teachers and as much of our administrative and support staff as possible in the observation and discussion of research lessons. By scheduling research lessons outside the school hours, after lunch on minimum days, we can go a long way towards permitting more teachers and staff to participate. By involving all teachers and staff in each of the year's research lessons, the impact of each lesson can extend outside of the individual teacher or planning team, and impact the school as a whole. Additionally, I believe we can refine our research question in such a way that it will be both more focused and more clearly applicable to the standards we must teach at each grade level, specifically by examining standards related to the base ten system. By focusing on this area and studying our

own curriculum as well as the translated Japanese curriculum, I believe we can use lesson study as a way to deep our pedagogical content knowledge across all grade levels and well beyond the scope of any individual lesson. I believe that through these changes, inspired by the Japanese lesson study we examined at IMPULSE, our school's lesson study practice can come to have a greater impact on student learning at a schoolwide level. We are lucky that so many of our teachers already believe in the potential of lesson study to improve teaching and learning and because of that they were willing to take on the challenge of a new and at times overwhelming professional development program. My hope is that over time we will see the effects of our lesson study in the improvement of our students' mathematical understanding and that this improvement will increase teachers' and administrators' faith in the practice of lesson study. In this way, we might even be able to gradually shift the mindset with which we approach professional development, putting faith in a teacher's ability to grow in their practice over time with the support of a collaborative process of lesson study. Even if only at our own school at first, the shift could have lasting and powerful effects for our teachers as well as our students.

Hanna Sufrin

My head is full of insights and ideas from my time in Japan with IMPULS; my heart is full of inspiration. Here are some of my most meaningful take-aways:

Whole-School Participation: The nurse! The kitchen staff! Teachers from all grades! For a member of a school team that divided up into small groups for each research lesson cycle, these facts about how lesson study is organized in Japan were revolutionary. I now understand how essential it is that every member of the school team participate in lesson study, with a strong sense of unity. If the ultimate goal is to impact every classroom and every member of the school community, then of course this makes perfect sense. It highlights for me how our school's attitude about lesson study - that just the small group from two or three grade levels should benefit from each cycle - was problematic. We need to shift both our goals for lesson study *and* our approach. We need to view each research lesson as an opportunity for *every* member of the school team to learn together with a shared vision for impacting every student, not just the lower grades or the upper grades. And we need to schedule lesson plan with a structure and protocol that makes this unity possible, as in Japan.

Joy of Math: Many of my students would tell you that they "hate math." I work very hard as their math teacher to change those feelings and that attitude, but with limited success. Observing lessons in Japan gave me a model for what enjoying math could look like for students. It looks like students holding their breath as the teacher reveals the day's problem. It looks like kids taking pride in every note they record in their math journal. It looks like kids jumping out of their seats to shout ideas about a teacher's question. I saw many teacher moves that led to this level of excitement: building the intrigue around the day's problem (*hatsumon*), motivating students with quotes like "This is too hard for you, I don't know if you can handle this," and bringing in pre-made materials that facilitated the "jazz" of the lesson. While these are teacher moves that I often make as well, seeing the effects of a true commitment to student enjoyment of math helped me to re-commit to this being a top priority for my lessons. I will think of the 5th graders at Ryuo Elementary School "oohing" and "ahhing" about the shapes presented to them, as I endeavor to hear all of my students say they "love math."

Instructional Research / Kyozaikenkyu: The poor quality of Oakland's chosen math curriculum is a challenge for our school, and I am quite envious of the Japanese math curricula available to teachers there. However, I feel slightly less discouraged about the prescribed curriculum when I think about incorporating more *kyozaikenkyu* into our approach to lesson design. When I think about how little we incorporated research into our lesson planning process as a research lesson planning team it is clear to me how much *kyozaikenkyu* would have improved the lesson that was eventually taught. There are other curricula, other guides, and even the Japanese textbooks to help us in a process that until now was dependent mostly on our own brains and our own ideas about the content. So while we still remain somewhat boxed in by a curriculum we are expected to teach, I am excited to explore how prioritizing *kyozaikenkyu* will change the way we deepen our lessons with the help of what's out there. This is a vision made possible by all that I learned about *kyozaikenkyu* while in Japan, thanks to the IMPULS team.

Board Work / Bansho: How I yearned to see successful *bansho* in action! And I most certainly did. I learned many ways in which I can change my own instruction using board work. These include: strategies for organizing the board more effectively, strategies for creating a balance between teacher writing of students' ideas and students writing on the board, strategies like color coding to increase understanding of concepts through the material on the board, strategies for improving student exchange through the use of the board, strategies for summarizing ideas on the board, and more. I feel far more equipped to teach lessons using *bansho* than I did going into the IMPULS experience, thanks to the lessons we observed.

Student Discussion / Neriage: There are many aspects of the math learning environment we observed in Japan that I hope to bring back to my own classroom in Oakland. I also recognize the many layers and the hard work behind those environments, and I endeavor to do the work that made them possible. One such aspect is the powerful student discussions we observed during the *neriage* step of many lessons, in which students responded to one another and to one another's ideas. We could see and hear that students were genuinely listening to one another and saw one another's ideas as the building blocks of the lesson. It is far more typical to see many students in my classroom check out when other students begin sharing ideas. Discussions often do not follow a thread that could eventually lead to a shared understanding of a concept, but are rather a potpourri of ideas without links to be made between them. The responsibility to make these links and build toward learning through the various ideas usually falls on me, the teacher. Instead, I want my students to do the building themselves, as was done in many of the lessons we observed. I am already beginning to plan how to lay the groundwork for this shift toward meaningful student discussion at the start of this school year, and again I have the vision for my goal thanks to what I observed in Japan.

Professional Development Philosophy: My school has a terrific approach to professional development, which is far more teacher-led than at your typical school in the United States. We have successful professional learning communities ("PLCs") that lead to fruitful teacher-led learning, and almost all professional development sessions at our school are led by teachers. That said, the philosophy of lesson study being centered around school-based teacher research as opposed to research from outside experts is a shift that I would like to see happen at our school. This past year we treated lesson study as one of many approaches to teacher learning for our team - it did not push us in a new direction for thinking about how we grow as teachers. As a member of the teacher leadership team at our school, I hope to kick off this school year with a discussion about what learning through lesson study means for our school philosophy on teachers' professional development. Lesson study need not only be our approach to improving math instruction, but can also influence how we research the changes that need to be made at our school and the collaboration

we do to make progress across the whole school.

Nurturing Children Through Math: Commentators, principals, former principals, and teachers all shared a message about the ultimate goal for students' relationship with math. Learning math, they repeated, should nurture students. We heard that the next steps from the lesson study experience should revolve around more deeply nurturing students through math. Math, therefore, is an important part of helping students grow into the best human beings they can be. It is a part of shaping their identities as thinkers and as members of a community. A trip across the globe to the United States would bring one to a very different message about why students should learn math: it's solely about the knowledge and the skills they will need to be successful down the road, and getting behind pushes them off a math track that we view as ambiguously essential to every student's success - despite the role that technology will play in their ability to do math down the road. We as a country don't really know why we want our students to be "good at math" and this most certainly affects the overall stressful approach to teaching math. It is not about the thinking and the discovery, but rather a checklist of skills. I want to feel less constricted by this checklist and more focused on nurturing my students through math; I am deeply motivated by the attitude in Japan. Curiosity, reasoning, critical thinking, communication, a willingness to struggle, and the satisfaction that comes from successful problem solving - these were the nurturing priorities I saw in Japan, and the priorities I want to put ahead of the standards checklist that ignores the "why" for teaching math.

One Lesson, One Problem: I was eager this past school year to shift to a problem solving approach to teaching math, and I experimented a great deal to make the shift. One of the most uncomfortable aspects of the change was centering lessons around only one problem. I worried about one problem providing enough "meat" for students' introduction to a concept. I no longer worry about this, having seen nine lessons in Japan, each centered around only one problem. I am far more eager and, more importantly more confident, to teach math through problem solving this coming school year. I have a model for how the right problem can lead to the most fruitful discussion, discovery, and learning. It is clear to me that if I take on the challenges of this approach, like designing that one ideal problem, my lessons will be far more meaningful than those I've taught using multiple problems.

The Knowledgeable Other: Before I learned more about the authentic approach to lesson study I was unaware of the essential role of the knowledgeable other. My school had the good fortune of having Dr. Takahashi present at our research lessons, and my understanding was that he provided commentary during the post-lesson discussions because he was our lesson study leader. Now I understand that - in addition to being our guru! - Dr. Takahashi was fulfilling an official role that we should always seek out whether or not he is available to take part in our research lesson. In Japan it was powerful to observe the importance of the knowledgeable others for each lesson and the impact of their commentary. I now understand how much value should always come from having an external and wise observer who can help the whole school team develop next steps that are not just based on self-reflection, but on a less emotionally invested and expertise-based analysis. I am excited to think about who will play that role for Acorn Woodland when we expand lesson study beyond mathematics.

Gratitude: Thank you for this experience - it was a powerful gift, not only for me, but for my students and my school. Every detail of the trip was so thoughtfully planned to maximize my growth as a teacher and as a friend of Japan. I learned a tremendous amount and will always be grateful for the opportunity.

John Christopher Aragon

Learning and Growing: Reflection on the IMPULS Program

My experience in Japan with the IMPULS Program was transformational not only for my view on mathematics instruction but for my view of education overall. During this experience I had so many light bulbs go off; so many "Aha!" moments; so many times when I thought, "This is a brilliant practice". It's difficult to articulate just how impactful this experience was but I will try to boil it down with the following words:

CLARITY

From the beginning of my experience with lesson study, I was a bit puzzled about the distinction between Japanese lesson study process and Japanese mathematical teaching practices. For example, during my first two lesson study cycles prior to this trip, I was not clear on what the lesson study cycle entailed. I also was introduced to so many mathematical teaching practices that many Japanese teachers utilize. After reading the pre work and hearing from the IMPULS team and teachers in Japan, it is much clearer to me what the Japanese lesson study entails. I think it's important for my school and district to make that clear distinction. I have spoken with many teachers who conflate the Japanese lesson study process with Japanese mathematical teaching practices. I do think that there are many Japanese mathematical practices that are wonderful and worth adopting; however, it's important to not confuse those with the Japanese lesson study process as a professional development tool.

KYOUZAI KENKYUU

This concept is one that I find very interesting and important. It is something that is very much devalued in the education system in the United States. I appreciate that this is valued by education professionals in Japan and I wonder how resource limited schools in the United States can incorporate this into our educational system. How can we make it systematic and sustainable at our resource-limited school?

GROWTH MINDSET

This experience made it clear to me that the lesson study process is not about having a perfect lesson and it's not about sticking to a script. Teachers should change course if needed. Teachers will and should make mistakes. This is how we learn. I appreciate that the teachers are focused on having a growth mindset. This speaks to lesson study and the Japanese education system. I commit to try to shift my thinking to a growth mindset.

EMPOWERING

It was very refreshing to see multiple Japanese teachers empower students to take charge of their learning. One teacher let students walk around to look at the work of other students. Another teacher gave students a problem and the tools to solve the problem with relatively little instruction; the students then went to explore. Another teacher gave confused students additional hints and questions that helped guide them in the right direction. I felt like these were very empowering strategies.

HOLISTIC

I am very inspired to see how Japanese schools take a holistic approach to education. So many aspects of the education system are focused on educating the whole child; they are not just focused on providing excellent academic instruction. For example, every student learns how to swim in school. This is a very important skill that children need to learn. In the United States, children may learn how to swim with their family but there is no expectation or requirement to learn how to swim at a public school. In fact, it is very uncommon to learn how to swim at a public elementary

school. We also do not have instruction on hygiene or eating practices. I am inspired to bring this holistic approach to teaching to my classroom and school.

DIFFERENTIATION

I am very interested in the idea of differentiation in the Japanese education system. Dr. Takahashi mentioned on the first day that the term "differentiation" is very trendy at the moment but the focus is more on providing entry points for all students. I am unclear how students who have learning differences or who struggle in school are given entry points; for some lessons, it seemed like there were students who were lost. How were these students supported in the following days or weeks? Are there interventions or small group instruction for struggling students? During one post discussion, the special education teacher offered the idea that struggling students should be given small models of the shape in order to have a clearer understanding of the problem. That was the first and one of the only times that I heard a teacher mention the support of struggling students in this way. I am interested to know if there are systematic supports or if teachers use their discretion to support these students. I'm also curious if this topic comes up explicitly in the lesson study process.

ENGAGEMENT

I was very interested in the level of engagement of the students. There were multiple instances in the week where students seemed to have a difficult time focusing during the lesson and the teacher did not try to redirect or control student behavior. I come from an educational setting where teachers feel the need to control student behavior in order to maximize learning. I have found that this often has a negative impact on learning. It was great to see that students were mostly allowed to behave how they want and Äi0they still seemed to be able to learn. There was one student that was moving from one seat to another. He clearly had a lot of energy and found it difficult to sit still. What sort of supports to teachers typically give students who are active and need movement in their learning? How does the teacher ensure that the students are engaged and understanding the content?

FORMATIVE ASSESSMENTS

I am very interested in how teachers in Japan typically monitor student progress. I found it very interesting that teachers did not give formative assessments at the end of lessons or during lessons. I come from an environment where teachers are strongly encouraged to give formative assessments at the end of every lesson (or weekly). I know that the lessons we saw are just a snapshot of the teacher's practice so we may not be seeing the formative assessments. But I still wonder, what sort of formative assessments does the teacher give in order to assess learning? Are formative assessments intentionally excluded from lesson study lessons?

HUMBLED

I am overwhelmed with gratitude and humility after having this experience. There is a wealth of knowledge among the participants and organizers of this program and I am deeply grateful to have had the opportunity to be a part of this program. I have no doubt that this experience will shape my teaching practice. I am a new teacher and I feel incredibly grateful that I had this experience so early on in my career.

GRATITUDE

I felt an incredible sense of appreciation towards everybody who welcomed us to Japan: professors, coordinators, teachers, graduate students, college students, administration, advocates, supporters, and everybody who helped. It is clear that everybody involved in this program poured so much time, energy, and love into this program. I greatly appreciate the opportunity to learn from experts. As a new teacher, I am beginning to better understand what effective mathematics instruction and

learning looks like. I am honored to have the opportunity to learn so early on in my teaching career. **THANK YOU!**

Kari Laux

I came back from the IMPULS program with my brain overflowing with thoughts, questions and ideas both about how to improve my instruction as a classroom teacher and about how to implement lesson study at my school site. My thoughts from the week fall into three major buckets; the things I didn't know about lesson study, what I have to do to be able to implement lesson study at my school site and how what I observed in Japan will change my personal teaching practices moving forward.

Though I had some experiences with lesson study before this program, personally observing multiple examples of the lesson study process in Japan helped to deepen my understanding. The first thing I learned about lesson study was how critical the problem selection is. The numbers chosen for the problem, the wording of the problem and the problem scenario (when applicable) are all such a big part of the research lesson. I saw throughout the institute the role a well researched textbook plays in this as well as the role of knowledgeable professionals who are aware of their content and the various ways it is taught. If you do not start with a meaningful problem, it is difficult for the discussion about the research lesson to reach a level deeper than the problem itself. The problem selection must be intentional so that the learnings from the research lesson can go beyond problem selection. Another thing I did not know prior to this experience was that the whole school participates in lesson study and it is a practice used in all subject areas, not just math. The idea of having the whole school be a part of bettering instruction aligns with our school's norm that the students are "all our kids" and we should all work together to give them the best they can have. Using lesson study as a space where the whole staff participates in discussion around instruction can help our school align on best practices and give the students a more coherent experience throughout their schooling. Lastly, when I was first introduced to lesson study, I was told that it meant teaching a lesson over and over again, working to learn from your mistakes and make it better each time you taught it. I learned that this is not the case, primarily because students are not guinea pigs who we will "try out a lesson on" when we have not yet given it much thought and also because there is no such things as a perfect lesson. So, teaching a lesson over and over again in hopes of arriving at the perfect lesson does not make sense. Instead, lesson study is about learning from each lesson, the process of planning it, teaching it, and discussion it afterwards.

In light of all that I learned as part of this program, I am motivated to make lesson study, in a more authentic form, a reality at my school site next school year. In thinking about how to do so, a few critical things need to take place. First, we need to create a year-long plan for research lessons. If we want research lessons to happen across grade levels and we want all teachers involved in planning teams, we have to have a master plan for how this is going to happen. Secondly, we need to prioritize the planning of research lessons. Time needs to be allocated for planning teams to meet to research their lesson and come up with the best possible lesson proposal. Also, if we want lesson study to be a whole school practice, we need to make it possible for the whole school to attend research lessons. Reconfiguring when research lessons take place would make it possible for more members of our school community to take part in this professional development and would also allow us to use lesson study as a means to align across grade levels.

While the primary purpose of this program was to observe lesson study, I inevitably learned a lot

about the Japanese methods for teaching mathematics as a result of being in Japanese classrooms. This will affect my teaching in multiple ways next year. I have previously tried to teach mathematics in a sort of hybrid format, using some problem solving and some "memorize the algorithm" teaching methods. It has become very clear that this doesn't work. When you try to combine the two, the students quickly catch on and do not engage in problem solving and instead wait for the day that the teacher simply tells them the algorithm. Problem solving seems optional. If I want my students to truly engage in problem solving, I need to approach all mathematics learning this way. Students needs to understand that the only way to learn math in our classroom will be through problem solving. By the same token, I have to shift the way students share their solutions and ideas with each other. When the whole class discussion is simply "show and tell" the students are prone to check out when a classmate goes up to share. If the only reason they need to listen to each other is out of respect or maybe to hear something interesting, it is likely they will often not listen. Instead, they should feel they need to listen because they are only going to reach new learning by listening to and building on each other's ideas. If the teacher is merely facilitating and pushing the class forward, the students then have to do the heavy lifting. It depends on them to think deeply and listen to each other to make connections and improve upon their ideas to reach new conclusions. However, this is only truly successful when the teacher has a clear plan in mind. Another thing I learned from observing Japanese math lessons is the role the teacher lesson plan and board work plan play in the successful execution of a lesson. Teaching through problem solving can be a series of rabbit holes if a teacher does not artfully direct student discussion to a desired outcome. The teacher must have the desired summary of learning in mind going into the lesson, know what student responses will help them get there, and have a road map designed for how to get from point A to point B. This is something I plan to work on this year in order to make it possible for me to do all of my mathematics teaching through problem solving.

This program gave me countless insights into both how lesson study is performed in Japan and how math is taught in Japan, many of which I'm sure I will continue to uncover as time goes on. These however are a few of the biggest realization that stood out to me. I am so grateful to have had this opportunity to learn from such a thoughtful, meaningful experience in Japan.

Crystal Ramirez

The IMPULS Lesson Study Immersion program has been an amazing experience that has helped me reflect on my own practices and learn about Japanese learning and lesson study. Having the opportunity to observe various classes that differ in age group and math topic has been eye opening and made me reflect on many things about learning, math, and my own practice.

One of the many things that amazed me was how education is thought about in terms of the whole child. Teachers do not just concentrate on the standards of the normal subjects of math, reading, writing, ,science, etc., but they also teach students the value of health, culture, respect, and responsibility. In the United States we touch upon these other subjects, but not to the extent that it was done in Japan. I was especially impressed by how much the students learn just during lunch. I loved how each student had a responsibility whether it was serving food or waiting respectfully until everyone was served their food to eat. Back home lunch time is usually chaotic with all students sitting in the cafeteria yelling and not really taking the time to eat. It was also great seeing that the students got to stay in the classroom and build more community with their classmates and teacher in a less formal situation. I also really appreciated how there is time for the

students to brush their teeth after they eat, which is an especially important habit to form in order to care for their own teeth.

I noticed was how detailed the research lesson was. I noticed that all the lessons were scripted and included all possible student responses throughout the lesson. Included in the research lesson was also an overview of the students, where they are in the unit, and any certain details about the class to keep in mind. All this information is very informative for observers, especially those unrelated to the school. Having this information helped me better understand each group of students and where they were in the lesson. Without having this information, one can come up with their own assumptions and not really understand the classroom environment and the type of community that the teacher has built with their students.

Each problem for the lesson was open ended and most allowed time not only for the student to work on their own, but to also work with a partner and/or group. Most all of the teachers allowed time for discussion among the students about the problem. This gave each student the chance to explain their own solution, listen to others' solutions and also review what they came up with and think about their own thinking. If teachers did not give time or enough time for this exchange of ideas, they talked about giving time or more time the next day when they continued with the lesson. Most of the lessons had very rich conversations and it was so interesting to see what the students had come up with as their solution and how this went along with (or did not) the anticipated student responses that the research group put in the lesson.

One lesson that I found really interesting was the first grade lesson. I was surprised by the length of the lesson and the amount of students in the class. Then on top of that to have 50+ observers is a very challenging situation and I commend the teacher for the great job that he did. I feel that the flow of the lesson was good and I think that most of the students understood how to get the number 4 and what it represented, but I think the confusion started to settle in when the teacher started asking about the expression and why it had to be a subtraction expression. This is about the point that I start loosing my students as well and struggle with explaining to them. As I looked around the room there was definitely a spectrum of understanding of the whole problem and the process. There were students that just drew the 2 teams, but didn't use any strategies to solve the problem and just stopped there. Then there were students that drew their pictures and were able to draw lines to connect the two teams and end up with 4, but never wrote down a mathematical expression for the picture that they drew. Then there were students that were able to draw the picture and write the correct mathematical expression for their picture. If I were to teach this lesson, I think I would allow more time for the students to work together and talk about how to solve the problem. I think that more students would have understood what they were doing if they had the opportunity to discuss solving the problem with their partner. I did see students copy their partners when they didn't understand something. I saw one student in particular who was on the right track, but since she didn't draw the lines to connect the matching 3 players like it was on the board and like how it was on her partners paper, she erased all her work and copied what was on her partners workbook. I would have probably ended the period once we go to the answer 4. Then I would have continued the conversation with my students the next day, revisiting the problem and discussing the expression and why it would be a subtraction problem. Overall, it was a great experience and I loved that I got the opportunity to observe a lesson being taught in the grade I teach in and concept that I struggle to teach.

As for the process of lesson study itself in Japan, I feel that it is an incredible experience. Even though it takes such courage for a teacher to teach in front of so many adults, the feedback is so helpful to have. Teachers seemed to have built a community among themselves where they feel more comfortable being straightforward about the constructive criticism they give. The teachers giving feedback not only give things that the teacher can work on, but they always remember to thank the teacher for teaching and sometimes give points of the lesson that they think went well. The teachers that taught are clear that the feedback they are getting is not personal, but things that can be reflected on for their own personal practice that will ultimately benefit the learning of

their students.

This whole experience has been invaluable. It was amazing to see teachers in Japan teach and I am grateful to have had the opportunity to see them in action doing lesson study. I have learned so much and I come home with more knowledge, enthusiasm, and courage to refine my practice of lesson study and share what I have learned with my colleagues.

Marna Wolak

I feel so very fortunate to have had the privilege and honor of traveling to Japan to learn about the Japanese education system, math instruction, and how Lesson Research is conducted in the place of its birth!

I returned home last week, and as I adjust to being back in the United States after such an incredible experience as an IMPULS participant and post-institute travels in Japan and Southeast Asia, I have already enjoyed many hours sharing stories with my colleagues, family and friends. During these conversations I have been asked over and over about my key learning's; what I'm "bringing back" on a personal level, to my own classroom, school, and district. My response to this question always begins with a short explanation of similarities and differences between Japanese culture and society and my own, and my strong belief in the profound impact these attributes have on public education in our given countries.

I should begin by stating that Japan is the very first country that I have ever visited where I haven't witnessed people living in poverty. Not to say that it doesn't exist, but in my limited experience, it appeared to me that the majority of the Japanese population lives comfortably in safe communities. I believe that the schools in Japan are a both perhaps the "source" and the "product" of that safety and security, …as having ones' needs met as a/by society is the norm.

Just as we were told several times by our Japanese colleagues during the institute, "Lesson Study is like 'air', an integral part of who we are as students and educators", it would be difficult to share my observations of math teaching and learning without first noting how impressed and in awe I am by the way in which public schools have been set up to truly ***respect*** and ***nurture*** the *whole child*, …something seemingly as fundamental as the "air". Many foreign education systems strive to emulate Japanese math instructional practices, but I don't believe this can really be accomplished unless we begin to look more deeply at the structure of the public education system in Japan and consider how we can begin to emulate it as well!

As someone who has always taught in schools filled with students who live in poverty and as someone in the struggle for social, economic, and environmental justice in the United States and globally, I was so moved by what is a **given** for EVERY child in Japanese public schools. We have all heard about the high level of academics in Japan, but for some reason little is mentioned about the fact that other areas of learning are just as revered as "traditional" academic areas of study. For example, in ALL public elementary schools in Japan, every child is given the opportunity to learn about and create art, study music, plant and watch things grow, learn how to swim, develop their fine and gross motor skills through games, be cared for by a nurse when sick or injured, eat a free, nutritious meal *prepared on site*, served by students and shared with their classmates, …teaching an appreciation for the food and the importance of sharing a meal with others. Children are not expected to behave as robots, they are allowed to be "kids", but at the same time trusted to be responsible and independent in the hallways, on the playground or soccer field.

Witnessing this school "context", where every child's basic human needs are being met, was so touching, and made me feel quite hopeful, but somehow at the same time I was also filled with sadness as I thought about the state of affairs in my home in California, one of the "richest" states in the nation, that also shamefully has the highest child poverty rate, and where in certain places an institution called a school might be mistaken for a prison by someone visiting from Japan.

Given that each child's social/emotional needs are being met in Japan, it's no wonder that when a math lesson begins, students are both eager and able to focus on their learning. In the classrooms I observed, every student followed the protocol or routine; taking notes, working independently, participating and listening attentively as their classmates and teachers shared their thinking at the board. Students appeared comfortable with the method of "problem solving" based learning: working alone, with a partner, in a small group, …and they were able to articulate their thinking in front of the entire class, even with 40+ sets of adult eyes hovering over.

Something that I see as another positive aspect of math teaching and learning in Japan is that when it comes to new concepts, there is an emphasis on depth over breadth. There are fewer standards to be mastered at each grade level compared to in the U.S., thus what is taught is given adequate attention and students have the time to deeply learn the concepts, instead of being rushed along to something new too quickly. I also found the curricular materials/text books to be of what I consider to be a very high quality. Lessons are presented in a simple, yet thoughtful and succinct way. And from what we were told, the textbooks aren't something created in a distant office by people with little experience with children or teaching, as often happens in my country. Instead, lessons are created by teachers and professors, then presented and tested for success using Lesson Research, therefore ensuring student accessibility and rigor. Something I noted in my reflection after our first day together was that I valued having the opportunity to study textbooks from different grade levels, and it was eye opening noting the sequence of problems presented for the development of a particular concept over the years. This is something that rarely, if ever, takes place in my school or district.

I was extremely impressed by how well the students I observed were focused, organized, and persistent. However, something I often wondered throughout all of our observations was what type of intervention is provided for struggling students. The teacher in the first classroom we observed provided some scaffolding by briefly calling students who were confused to the front of the room to work with him, but other than that I didn't see teachers providing additional assistance when there may have been confusion. On a few occasions, teacher observers and the knowledgeable other also shared concerns about students who didn't appear to understand the lesson.

The lesson that I was most impressed by took place in a 7th grade classroom at a university "attached" school. The concept at hand was slope, and small groups were given the challenge of recreating a graph presented by the teacher using a specialized tool. During this lesson I observed the highest level of student engagement, and even with the language barrier, I could actually witness students change their thinking based on trial and error, the ideas of their own group members, and their observations of other groups. Equally as important, I noted that students were comfortable interacting with each other, and they didn't appear to be afraid to make errors, persevering throughout the entire lesson. I attribute this to the culture of respect that has been fostered throughout students' educational experience.

In terms of what I observed of Lesson Research, I was intrigued by the similarities and differences between "post-lesson discussions" in Japan and in the U.S.

In my district, we stress that Lesson Study observations and data collection must focus on the students and how they engage with the task. We then discuss trends and offer suggestions for improvement. But the majority of the post-lesson discussions I observed in Japan appeared to be focused on the teacher and the moves s/he made during the lesson.

It was fascinating hearing the comments of the *knowledgeable other* during the post-lesson discussions. It was apparent that the people chosen to fulfill this role are indeed

very knowledgeable and have an almost artistic gift for sharing their thinking; first drawing attention to the positive aspects of the lesson, next sharing their mathematical expertise about the concept at hand, and then moving on to points of concern and suggestions, all in a way that is not cause for defensiveness on the part of the presenting teacher. I also found it intriguing that many of the questions brought up by both the knowledgeable other and the teacher observers were very similar to the concerns shared by colleagues at my own site this past school year. For example, how do we get students to more thoroughly explain their thinking and question each other or request further explanation when an explanation is unclear? How can we get students to better connect past learning to their current studies? And, how can we provide more opportunities for students to integrate their learning in math as well as in other subject areas?

In closing, I would like to emphasize how proud I am to have been part of this international delegation of educators who strive to improve teaching and learning, with the goal of increasing student achievement in our home countries. I learned so much from observing our colleagues in Japan *and* from other participants. I am excited to bring this learning to my community and at the same time stay connected with everyone I had the pleasure of meeting, confident that we will continue to grow together. This experience has pushed my thinking and challenged me to reconsider what is possible. I am forever grateful!

Brent Jackson

My participation in the International Mathematics-teacher Professionalization Using Lesson Study (IMPULS) immersion program allowed me to gain insights into how lesson research can be a powerful learning experience for teachers across a school as well as further develop my understanding of mathematics pedagogy. As I prepared to participate in the program, I was excited to see perfect mathematics lessons that were created through the lesson research process. Even though I know that lesson research is not about building the perfect lesson I still had this perception. In this final written reflection I will write about critical incidents - such as seeing less than perfect lessons- during the the IMPULS program and what I learned from those moments. I will discuss my learning from the myth of the perfect lesson (including how I learned the most from the more imperfect lessons), the shape of mathematics in lessons I observed in terms of students' mathematical agency and authority, and noticings that will help me to better grow and institutionalize the lesson research practice in my local context.

As mentioned earlier, I was anticipating to see perfect mathematics teaching during the immersion program. What I actually saw were lessons with ambitious goals that sometimes had pitfalls in the planning and/or implementation. There were two lessons in particular that were less than perfect, and it is from these two lessons that I learned the most about lesson design and implementation. One lesson was an elementary division lesson and the second lesson was a high school statistics lesson. I will briefly describe the two lessons below.

The first lesson was an elementary lesson about division. In this lesson, students were to find a way to divide 48 by 3. This problem was different from past problems students had worked on because students did not know the related multiplication from the fact family to solve the problem (i.e 16 times 3 equals 48). The second lesson was a high school statistics lesson regarding random sampling. Students had previously worked with a set of circles containing varying diameters on a printed sheet of paper and were to conduct a random sample and a non-random sample (called

"intentional sample" by the class). During the public lesson students were asked to take the data from all of the students' random samples and non-random samples in order to determine which method was better for getting closer to the mean.

These two lessons revealed an extremely important design feature in lesson planning - the context that the mathematics is being applied in must be carefully considered to determine whether it supports the goal of the lesson and unit. In these two cases the context did not support the mathematical goals. In the division lesson the context was introduced that there were four boxes, each containing 12 popsicles, that needed to be divided among 3 students. With this context, a sensible way to approach the problem is to fair share 3 of the 4 boxes. Then fair share the popsicles (12) in the remaining box so that each student receives 1 box plus 12/3 popsicles, or 12 popsicles + 4 popsicles. The goal of the lesson was to steer students to decompose the 48 into 30 + 18, two numbers that they know are multiples of three, and then by knowing the fact family, students would be able to determine that quotient as 30/3 + 18/3 = 10 + 6. Decomposing the dividend in this way was not supported by the context which led the lesson down a meandering path.

In the statistics lesson students were considering whether the random samples or non-random samples where better at approximating the mean of the population of circles. During this activity the students had access to the whole population of circles and during the class discussion there was a lively debate about the students' non-random (intentional) samples. Students were arguing that their intentional samples were actually random because they didn't consider the proportion of each size of circle in their intentional sample. Students were using this premise to reason that if they were more intentional (by sampling each in proportion to population) the non-random sample would better approximate the mean. This lesson was being taught as part of a larger unit in which the students are asked to conduct a survey about the "busyness" of high school students at different schools across Tokyo. By putting the students' statements into the context of the larger unit problem and asking whether or not one might know the proportions of "busy" students, students might start to see that their reasoning is incorrect when the whole population is not already known. Considering the larger context of the unit may have helped to make the objectives of this lesson more attainable.

In contrast to the two lessons discussed above, we observed a research lesson on division in which students considered the meaning of the remainder. The computational problem was 3 ½ divided by ⅕ and the context to support the problem was kilograms of ground meat being divided to make patties. The quotient is 17 ½ and students are asked to consider the meaning of the ½. Does the ½ mean patties? ½ kg? The context of this problem helped make sense of the units of ½ being patty (half of a ⅕ kg patty, meaning a patty that is 1/10 kg). If it were ½ kg, then one would be able to make more ⅕ kg patties. This context supported making meaning of the computations students were working in.

The research lessons we observed were all structured in a similar way. Generally, the teacher posed a problem, students worked individually and then the teacher chose student work samples to structure a discussion towards a mathematical point. Sensei Nakayama stated during his debrief after the sixth grade area of curved figures that he, the teacher, was creating the flow of the lesson and that it would be better if the students were creating the flow. Sensie Nakayama's lesson, like most lessons we observed were focused on individual work versus collaborative work. I am wondering how the structure of the lessons from individual time and shift to class presentations make affordances for or limits the development of students' mathematical authority. From my observations, the norms in the classroom are such that students have developed mathematical agency and it appears in the way students engage a majority if students have positive

mathematical identities. It was rare to see a student not engaging in a problem. I am interested to know why there is little time for students to share ideas in small groups - where they would have more time to debate and solidify ideas among each other before a class presentation. I am also wondering if the patterns in presenting solutions becomes routine and whether students believe that if they are chosen first they must have an incorrect solution or less sophisticated answer. I also wonder if the carefully planned board plans limit the teacher's ability to make the mathematics the students' mathematics. An expert commentator during the volume lesson stated something to the effect that during problem solving lesson we want the students' individual ideas to become class shared ideas. Do the students believe the ideas are really their ideas - or do they believe them to be the ideas the teacher pre-selected students pathways. Further, the same commentator stated that students should be asked to repeat what each other are saying in order to clarify and make sense of other students' ideas. In this way, the conversation is between the students and not the students and teacher which may help students see the mathematics as their own.

During one expert commentary, the outside expert made a statement similar to this: "we want students to think about why they couldn't share their ideas, then work to refine their ideas." When miscommunication is happening in the classroom this is because they are talking about something sophisticated that the other student doesn't have all of the knowledge for, so students have to revise explanations and use their common experiences and expectations, what they have learned together, their shared understanding… The teacher's work is to bring everything together and bring up to the grade level mathematics -- pull out the more sophisticated ways of thinking. I am wondering about how we make room for more students to share their ideas so that they have to refine their ideas?

I applied to participate in the IMPULS program so that I may learn how the practice of Lesson Study is supported institutionally - and what aspects of the practice make the process powerful to teacher learning. In my local context, we do a version of lesson study, but I wanted to know how the missing parts are creating missed opportunities for professional learning. I noticed two aspects of the lesson studies that I believe can make our lesson study practice more powerful. These two aspects are the development of the school-wide research theme and partnerships with knowledgeable others.

The school-wide research theme makes the lesson relevant and meaningful to all teachers at the school. The research themes tend to be broad questions that cross disciplines. For example, developing affective and social dispositions that help create curious learners. The themes allow all teachers to focus their observations for evidence that will help answer their research question. Secondly, knowledgeable others as final commentators are able to speak to the whole staff about the research theme the all staff are interested in better understanding. They use the context of a particular lesson, but they really speak towards broader practices and habits of teaching and learning. The expert commentaries are essential to continue the learning and push the teaching teams into thinking in new ways. I also saw that knowledgeable others can help develop the lesson plans by providing critical feedback before the research lesson. There were lessons in which knowledgeable others were not used in the planning phase and the lessons were less effective.

As I work to grow the Collaborative Lesson Research in my district I better understand the essential role that school-wide research themes can play in helping all teachers learn from the lesson. I have better understand how we might partner with the local university and math project to provide knowledgeable others to help during the planning phase (helping the individual team learn) and provide knowledgeable others as final commentators (helping make learning from the lesson relevant to all teachers within the school).

Rebecca Setziol

What did I learn from Project IMPULS?

I have had 2 years experience with lesson study and teaching through problem solving. I have also attended the lesson study alliance conference in Chicago twice. These experiences pale in comparison to the insights and knowledge gained through the IMPULS program. First, I was incredibly inspired by the level of teamwork, cooperation, and dedication to the practice of lesson study in Japan. Teachers and administration working in tandem focused on a common goal: the theme of the research lesson. I was amazed at how the teachers of the research lesson AND the administration were receptive to the feedback from fellow teachers and the knowledgeable other. The feedback was then turned into the focus of the next research lesson. Brilliant.

Another insight into why lesson study is so effective in Japan is the fact that the results of the lesson study cycle are published and distributed to other teachers and in some form to the parents. This keeps all on the same page!

I found it very inspiring that an overarching theme among the numerous schools we visited was "nurturing students through mathematics." Many research goals surrounded students sharing their thinking and student satisfaction/ happiness at the end of the lesson. Much of the post-lesson discussions focused on the teacher moves: questioning of the students, the way in which students shared their ideas, and who did the most talking (teacher vs students). Teachers also spent a lot of time thinking about the beginning of the lesson and how to create drama and excitement to entice the students. Although many times this left too little time for student discussion it did add to the students getting really excited about MATH!

Lastly, I felt that attending the district open house research lesson was a highlight of the program. Seeing teachers and administration from all over attend a lesson on first grade subtraction and its complexities was exceptional. Prior to this trip I only knew of the "in house" lesson study. I had not heard of the district wide and cross-district lesson study opportunities. The cross-district/national lesson study conferences where teachers and administration develop new ideas for teaching chosen topics, investigate curriculum sequences and content are truly inspiring. Teachers are truly viewed as professionals and have direct input on developing curriculum. This was/is mind blowing.

How will I incorporate this "mind blowing" experience?

As a classroom teacher in the US my power is limited. Here are just a few of the changes I intend to make:

First, I will have a parent open house fairly early in the year. Although it won't be a lesson study/research lesson with a post-lesson discussion and knowledgeable other, it will be a time for me to showcase teaching through problem solving, math journals, and the paradigm change: students as teachers-teacher as facilitator. Additionally, when I do participate in my next lesson study at the school I will help facilitate a newsletter for teachers, staff, and parents, which outlines the findings and next steps. Some teachers and parents at my school didn't exactly "get" lesson study and why we were dedicating so much time to the process. A newsletter would help bridge the gap and make everyone included and excited.

Although it is not in my power, I will try to encourage my new principal to allow us to hold our research lesson on minimum days. On Wednesday, all students are dismissed at lunch. It would be easy to get permission for a class to stay and have that teacher present the research lesson. That way ALL teachers, staff, and admin at the school could be present. Seeing the direct benefits of this in Japan has motivated me to make this happen. Even if we aren't (yet) a full lesson study school,

having all present at the research lessons seems like a giant step in the right direction.

In Japan it became apparent that the Kyouzai Kenkyuu was a necessity for a successful lesson. I will continue to use the Japanese textbook as well as other leading thinkers such as Van de Walle to study best practices, scope and sequence, and content. Studying the standards as well as the best way to deliver them will help me be a better teacher/facilitator of discussion.

Finally, I will continue to seek out research lessons to attend in my area. During my time at IMPULS, I have befriended several of the teachers from California. They have all pledged to invite me to their research lessons so we can continue learning from one another. Hopefully, one day I can envision a cross-district lesson study here in California!

There were many practices I saw in Japan not directly related to lesson study that I will implement.

I love that the students eat real food together on real plates with real napkins and chopsticks. The food made at my school is processed and heated in a microwave. Students rarely use cutlery and if they do it is a spork. I am inspired to go and purchase plates, cloth napkins, place mates, and real forks and knives and hold a monthly lunch in my classroom. Here, just as in Japan, students can learn about healthy eating, polite conversation, and bond as a class. Hopefully, my classroom parents will pick up the charge and each take a turn cooking for our class-me first, of course.

In Japan, I saw that teachers sit together in the teacher's room at a long table. Our lunchroom is bare and teachers rarely eat together. What if the tables were arranged as they are in Japan, and we started working and eating in our teams, surrounded by other teams/grade levels? Our fractured and isolated staff might come together. I will start by asking my 2nd grade team to make this move.

I was surprised by the level of normal crazy child behavior I saw in the classrooms in Japan. However, when the lesson started students got right to work and stayed in that zone until the lesson ended. I loved the practice of the students starting the lesson with a bow and then signifying the end with another bow. I think this is a great practice. It lets kids be kids and also know when it is time to focus and work. I will show the video I took to my class this year and ask them to come up with our own opening/closing to each lesson.

Finally, I will focus on nurturing my students through mathematics. Helping them find joy, self-esteem, and perseverance through problem solving will me by main focus. School should be a place of fun and learning should be exciting. I will remember the students cheering as a teacher was pulling out a shape from the mystery box. I will remember students standing in front of motion calculator trying to make a graph by running, walking, hopping, and laughing. And I will remember the little first graders squeal with delight when they saw a quick movie of themselves playing dodge ball. I want that for my class. I want those smiles of delight. I am ever so thankful that I was there in Japan to witness what is possible.

Megan Mahoney

Before I discuss my amazing experience in Japan with Project IMPULS, I want to give a little history about my path to Japan. It started about two years ago with a reluctant introduction to

Teaching Through Problem-Solving (TTP). When I say reluctant, I mean that I was in disbelief that one problem a day could develop with our students the mathematical practice, skills and perseverance that we hoped for each of them. However, my district at the time had just adopted math materials that were not reaching all students and boring me as a teacher. There was no engagement at all and as a result, there was very little interest in our daily math lessons. It was as if I were instructing empty desks. The students just wanted to work ahead in their practice books and saw no value in problem solving or thinking mathematically. Actually, it was difficult to engage the students to approach problems; they just wanted easy steps given to them. This was the opposite of what I hoped for my students. As with any content area, I wanted them to understand the interconnectedness between the skills learned and situations for application. So, while somewhat reluctant and with many questions, I went to observe a fifth grade teacher at my site teach a TTP math lesson.

From the moment I entered the room, I noticed something was different in the classroom. The students were actively engaged. Each child took responsibility for their materials and understanding the problem that was posed on the board. They discussed and asked questions about the context and deeply wanted to understand what it was asking. I knew right away that there must be something to this TTP instructional method. Then came the discourse and I was blow out of the water. After a bit of time of independent problem solving, the students were asked to find a partner and discuss the problem, not the answer, but the strategies for solving the problem. The students' use of academic language during the discussions demonstrated the authority and ownership of the solution path. It was evident they understood what they were discussing and truly wanted to understand how their partner thoughts about solving the problem. That was exactly what I wanted for my own students and I was hooked! I wanted to start using the TTP instruction method right away.

Within a week, my second grade teaching team had developed a strategy to introduce TTP with our second graders by creating a progression of problems that would allow the focus of the lessons to develop the routines of the process. It was at this point that our site math coach, Jana Morse, approached my teaching team to participate in a Lesson Study cycle to deeply develop the concepts and the TTP process. Now, I need to explain something that made our math coach a bit unique. She has participated in the 2014 Project IMPULS program. With her experience in Japan, my team benefited in ways we can only begin to understand some two years later. So since we were mere fledglings in the TTP process, we all jumped into the process without knowing exactly what we were getting ourselves into; we only knew we needed more support to continue this process.

Through my work with the Silicon Valley Math Initiative over the years, I had some awareness of the Lesson Study process. However, it had been a few years and I went into this experience with a sense of newness, as I wanted to experience it with fresh eyes. Little did I know at that time that Jana had only six-month prior had returned from Japan as a participant in the 2014 Project IMPULS. To our benefit, she had gone into her IMPULS experience with very little knowledge of Lesson Study and TTP. I believe it is for this reason that she was able to create a pure and more authentic Japanese style Lesson Study process with my team. It is as a result of that initial observation in January of 2015 and the Lesson Study cycle in the spring of 2015, that I was inspired to attend the Lesson Study Alliance conference in May 2015 with a team of ten from my site, which ranging from an administrator, to teachers that had no knowledge of what Lesson Study or TTP was, to others staff who had some understanding of Lesson Study. In Chicago, I saw the powerful impact of whole-school Lesson Study and started to develop a plan with the team on how to develop into a school-wide process.

As a member of my site leadership team, I worked to develop a two to three year plan to establish school-wide Lesson Study. In the fall of 2015, the leadership team identified a school focus on building student and teacher understanding of Alan Schoenfeld's *Five Dimensions of a Mathematically Powerful Classroom* and a specific focus on Agency, Authority and Identity. It was the leadership team's thought that both lesson study and TTP were the perfect venue to support a shift in instructional practice needed to support the development of Agency, Authority and Identity. Over the course of the 2015-2016 year, the leadership team planned opportunities for the school community (staff, administrators, School Board members and larger parent community) to develop their understanding of Agency, Authority and Identity and to create opportunities to adjust classroom practices in order to build Agency, Authority and Identity with students. During the 2015-2016 school year, there were two Lesson Study Cycles (a fall and spring cycle) and there were four teams of teacher from five out of six grade levels who participate in at least one of the cycles. By the spring of 2016, the work we were doing with TTP and Lesson Study had spread throughout the district and there was much interest and curiosity about what we were doing. As a result, the Research Lesson observers grew from a few site teachers to school board members, district administrators and teachers from a variety of grade-level and district sites.

It is during this time that the opportunity to apply for the 2016 Project IMPULSE presented itself. I felt it was the perfect opportunity to deepen my understanding of both Lesson Study and TTP to continue to develop the work at my school site and to bring it to other sites in my district and possibly beyond. It is also during this time that my school site lost our administrative support as the site principal moved schools and the district-level administration was less than supportive of the Lesson Study process. I started to feel like I was fighting an up-hill battle to protect what I thought and felt was best practice for students in learning mathematics, TTP, and Lesson Study, a professional growth model which promoted real-time teacher learning by deepening understanding of the content knowledge and improving student learning through analyzing student work. Completing a Lesson Study cycle is both powerful work and hard work. I was confused that I was now fighting to be able to continue the work. It is at this point that I embarked on the journey to Japan.

I went to Japan with the desire to gain a deeper understanding of how to be a leader in the field and bring the powerful processes of TTP and Lesson Study to others especially in the face of potential administration opposition. I feel that in today's world, these processes make the most sense to develop agency, authority and identity in our students. It is my belief that if our students can take ownership of their own learning and understanding, they will become more productive and positive learners. We will hear fewer adults saying something like: how does geometry apply to my life or I am not a math person (not to mention how these message translate to children). As a result of my participation in the Project IMPULS, I saw a reality where students were engaged in their learning and understanding. They were problem solvers and looked for patterns in their world. I saw students reflect on their learning and make connections from one lesson to another. I saw teachers professionally collaborate to bring out the best in their students and to build not only engagement in the lessons, but authority with the understanding that they, as students, have a responsibility to be active, not passive, learners. These are only some of the powerful impacts from my involvement in Project IMPULS that I will continue to process and develop not only in my personal teaching practice, but also among all teachers and school community members I encounter. While my 2016 IMPULSE Project experience came to an end, it is only the beginning of my understanding of how it will continue to impact me professionally.

Now, as I sit and ponder my role in continuing the both Lesson Study and TTP with my site and district with the lack of administrative support, I carry with me both the inspiration of my Project IMPULS experience and the dilemma of moving forward in a way to brings all constituents along

with the process. As a teacher leader in my district, I hope to continue to spread this good work. One area that can be improved, and that the Japanese schools do successfully, is to create an avenue of communication to explain the hard work of the teachers and students through both lesson study and TTP. The way the Japanese schools publish the Lesson Study document establishes the professionalism of the profession, creating more respect and understanding of the process in the larger community. With this understanding, will come further support. Additionally, I was inspired by how the entire school staff is involved in the Lesson Study process and observes the Research Lesson. To me, this not only builds community, but it also creates a continuity of the learning. I can only imaging the potential deep of learning when all site members, including custodians and office staff, can support the students in developing the school theme. Finally, the invaluable impact of the administration's participation was evident in all Japanese schools. I witnessed site leadership directly involved with all stages of the lesson study process. This involvement of administration not only inspired the staff, but also encouraged the continuity of the school theme throughout the entire school. One particular and easy piece to implement, is having the administrator actively involved in the Research Lesson debrief in some capacity even if only to capture and restate the key point that the Knowledgeable Other mentions.

I biggest piece I carried away from Japan is the masterful way Project IMPULS modeled for the participants the TTP process. All the leaders, in particular Dr. Takahashi, demonstrated the power of the instructional practice. As I continue to work with teachers, administrators and the larger community, I will continue to draw on their modeling to persevere through adversity to continue to bring this good work to others.

Rebecca Zisook

There are some experiences whose value cannot be known until days, weeks, or even years down the line, after the experience itself has come to an end. I believe that my time in Japan will be one of these experiences. Though I reflected daily during my time as a participant of Project IMPULS, and have written the below reflection more than a month after the program's end, still I believe that I will continue to learn from my experience on the program. Some learning will, no doubt, be applied to my teaching this school year, and some will be gifted to me in my career as the years pass. I remain immensely grateful to have been given the opportunity to observe Japanese Lesson Study in its birthplace, taking a deep dive into mathematics teaching and learning.

There are many things I observed in Japan that simply impressed me. For one, I was blown away by the way the Japanese schools that we visited seemed to nurture the whole child.

This is something that we say we believe in in the United States, but rarely do we see it actually at work. The students that I observed in Japan were imbued with trust and respect, taking on responsibilities that gave them ownership of their world. For example, the students, even at six years old, were in charge of cleaning their classrooms not custodians, but the children themselves. Children also served lunch to their classmates not the carboloaded, highsodium, precooked, packaged meals I see in Chicago, but decent, healthy, balanced meals, cooked onsite that day. Each child was responsible for bringing his or her own placemat, usually a thin, patterned cloth, to shield their desk while eating. The children brushed their teeth and washed their hands at the communal sink outside the classroom. Many times, children playing outside were unsupervised. They were simply expected to play, and to work through their own conflicts.

At some schools, students had the option of grabbing a unicycle from the wall and teaching each other or themselves to ride it. After 10 minutes or so of play, they were expected to make their way back to the classroom for the next lesson. And they did.

This trust and independence permeated through the mathematics class as well. Students were expected to keep meticulous notes in their notebooks. And they did. Students were expected to be engaged. And they were. Students were pushed to persevere, to make sense, to challenge each other's reasoning, and to help their peers understand. Time and again, they did.

Before the math class began, and any class, for that matter, student leaders announced the beginning of the lesson, and all greeted each other with a bow. At the end of the class, they ended the session with a group bow, formally bringing the lesson to a close. While I don't know that I will adopt this practice in my own classroom, I did appreciate the gesture as showing great reverence for the learning process. After the lesson, children were sent off to play outside, or they could stay in the classroom if they so chose.

Certain elements of the educational system in Japan seem more complex than a simple matter of "try it at your own school!" Rather, they are steeped in many generations of history and layers of culture and geography. I am grappling with those differences now. So often, our attempts at schooling in this country (the U.S.) revolve around controlling children. What if we shifted our focus, from "controlling," to a term I heard used by educators (especially administrators) repeatedly in Japan a call to cherish our children? What if we focused on nurturing children through mathematics? What if we could allow the children in our classrooms to scream in excitement with their hands raised, as the Japanese children call: "Hai! Haiiiiii!"?

And instead of punishing children for calling out of turn, what if we harnessed that energy and enthusiasm, using it to imbue the mathematics with that same sense of urgency, mystery, and pleasure? What a powerful shift this would be for our kids, for our country, and for education as a whole.

One advantage that the Japanese teachers seem to have over teachers in other parts of the world is the quality of their resources, namely, their textbooks. I realized while in Japan that the use of quality resources is essential, and that it greatly enhances teachers' practice of kyozaikenkyuu. Many textbooks, as I understand it, are also responsive to Japanese teachers' use of them, and will change the numbers used in a problem, for example, based on teacher feedback. So often in the U.S., on the other hand, our curriculum textbooks feel minimally useful, if not detrimental to students' understanding. Kyozaikenkyuu then becomes a process of "weeding out" the worst resources rather than studying a trustworthy, vetted by teachers text.

Additionally, the fact that Japanese teachers' research lessons are published and can be purchased in large bookstores blows my mind. What a way to show, as a society, the value of the work of teachers.

Another realization I had while on Project IMPULS: Everyone needs to be onboard.

Teachers need to be onboard, not in a way that is forced, but in a way that accepts that this is how it is here and this is just what we do. Many problems arise in the US education system when "new and improved" instructional methods, curricula, or one size fits all reform emerges onto the scene. The method or structure is forcedly implemented, often in a way that lacks the proper resources for fidelity. Then the method or structure fails. Teachers are blamed, or worse, disenfranchised communities are blamed. The method or structure is phased out or abandoned, leaving the system worse off than it was before. I believe that many teachers and administrators who are unfamiliar with Lesson Study may see it, too, as "just another new reform method," one that will be phased out soon enough anyway, and therefore is not worth pursuing. That is why we, the teachers who have been given the privilege to see Japanese

Lesson Study in action, now have a responsibility to speak truth about it, to nurture its development in our own settings, and to start small by helping our colleagues and administrators to see its benefits. The "teachers' room" in Japanese schools was also a revelation. This is one thing that I feel my school, and other US schools, could adopt relatively easily. We simply need a vacant

room in the building. We could put tables or desks together, as well as some incentive to visit (like a coffee machine!) and begin to gather ourselves daily in this space. At first, I imagine it would feel forced, but I believe that after enough time, this process of gathering, sharing, and being together would serve to benefit us. It may help us (US teachers in general) to collaborate on instruction if we simply spend more time with each other, even in a casual way.

Another takeaway for me was that the profession of teaching is not to be taken lightly in Japan. What I observed were groups of professionals who were deeply reflective, striving to improve, and spending hour upon hour delving into the subject of mathematics, asking themselves how best their students might learn, and pressing forward when their tactics were unsuccessful. I saw entire schools of teachers being released from their classrooms in order to observe one teacher's lesson, the students dutifully completing their work unsupervised! in their classrooms until the bell rang, signaling the end of the day. I saw administrators so valuing the development of their teachers that they called a districtwide open house to observe teachers' lessons and participate in this process of Lesson Study. I am convinced that this is how student success is achieved by supporting teachers. Teachers who not only want to serve students and who are doing their best and pushing themselves every day, but whose society values them and their work, and recognizes that in order to do the job right, teachers need to be supported. Teachers need to know that they can try things teaching moves in the classroom, and not be chastised or whispered about quietly by their colleagues. Teachers need the space to reflect in an environment in which that reflection is met with openness, acceptance or even praise, and nonpunitive opportunities for growth and collaboration. But these practices can not be applied to the U.S. educational system all at once, in an effort to overhaul or "turn around" the current reality. We must start where we are. We must gradually approach the ideal that we wish to exist within. One good place to start could be by changing the way we train teachers, including being more selective about who may participate in a teacher training program. We also must compensate teachers in a way that shows that we revere their work.

And we also must recognize, as a society, that teachers cannot be singly held accountable for the systemic issues of poverty and racism that plague our country. Rather, we must recognize education as a system that exists in conjunction with every other social, political, and economic system, and find ways to support children, families, and teachers in an holistic way.

One final gift that was given me by this opportunity is that because of Project IMPULS, I now feel I have trusted educator friends all over the world; people who I can call on, debate with, bounce ideas off of, and check in with about the progress of the practice of Lesson Study in their own context. This new professional network is just one of the invaluable and lasting results of the program.

Shelley Terzian

Introduction

Participation in Project IMPULS benefitted me as an American educator for the following reasons. First, I was able to learn about lesson study and mathematics instruction in the Japanese context. Next, I observed how math teachers reflect upon their teaching to improve their own pedagogy. As a participant of Project IMPULS, I was exposed to the many aspects that make schools in Japan successful by interacting with school children who were excited to learn about me too. I discovered that Japanese school children learn more than academics in a school day. They learn about healthy eating habits, self-care, and socialization. I wonder why more countries (such as the USA) do not implement these ideas.

Lesson Study as a Model of Professional Development

Project IMPULS introduced to its participants the Japanese model for professional development, specifically in the subject area of mathematics. The professional development model introduced is called lesson study and is implemented in the Japanese educational system on the national, district, and school levels. Its purpose is to bring educational professionals together, collaborating on teaching and learning. On the school level, (and in the case of teaching mathematics in Japan) lesson study is a natural collaborative process teachers use to align their teaching practice to the Japanese National Curriculum. It is also a natural transformative approach to teaching and learning. It is so natural, that Fujii claims it is "like air" and hard to decipher its structure (Fujii, 2013).

Lesson study as a professional development model for American schools could be useful. In fact, Takahashi and McDougal claim that, "given the lack of progress in US education at changing teaching practices, it is worth considering other models of professional development than what is commonly used, (Takahashi and McDougal, July 2016)." The above quote poses an important question - how do we encourage American teachers to engage in lesson study to deepen their instructional knowledge of curriculum standards? Knowledge gained from the Project IMPULS immersion program can only benefit educators looking to assist in the cause to transform teacher training.

The Teacher's Role in Lesson Study

As observed in the 2016 IMPULS Program, Math teachers in Japan begin their lesson study with the technique of " *kyouzai kenkyuu.*" This first step is crucial because it involves Japanese teachers carefully analyzing the course of study and reading pertinent research articles about a specific content area. Next, teachers examine the curricula and relevant texts. This step encourages the teacher in making clear decisions about lesson topics that relate to a school wide theme. The goal of having a theme is to target an important area in mathematics instruction, thus improving teaching and learning school wide.

After careful reflection of the math lessons observed during project IMPULS, I learned that lesson study is a natural process for teachers. Further, its aim is to ameliorate classroom instruction by teachers reflecting on how they can clearly communicate curriculum standards to their students. In the lessons observed in Project IMPULS, it was evident that each teacher cautiously designed their lessons, and then scrutinized his or her practice during the post-lesson discussion. The teachers used lesson study as a problem solving lens to plan and discuss lesson details with intentionality. Although the chosen math tasks for the students to complete in each observed math lesson was from grade-level appropriate math material, the process of lesson study is not derived from a textbook.

One example of a teacher's commitment to lesson study was observed in the fifth grade lesson taught by Mr. Yoshitsugu Ito at the Ryuo Elementary School. The goal of this lesson was to have students use prior knowledge to determine the volume of a given figure. The purpose of this research lesson was to implement a *Mondai Kaiketsu Gakushu* (problem solving) format. The above included the students engaging in an independent problem solving activity. Students would also explain their answers and their understanding of the other students' responses. In addition, the lesson plan explained the roles of the teacher, the students, and the observers. The observers' role was to focus on the following three areas: 1. Were the goals of the lesson achieved; 2. Could students own their own ideas toward solving the problem, and 3. Was the use of the ICT equipment effective for students to share their ideas.

The following describes my insights after observing this lesson. Mr. Yoshitsugu Ito realized he was too focused on finding the volume of the figure instead of working with each student individually. He did not reach the goal of this lesson, which involved helping students achieve ways to find multiple approaches to finding the volume. Since he was too focused on the content of the lesson, he was unable to help each student develop a strategy they could use to tackle the math problem.

During the post-lesson discussion, the knowledgeable other also noted the teacher could have reached more class members by having students repeat the answers of the students that tackled the math problem successfully. The above could have contributed to multiple students' understanding of the math task.

Valuing Teaching and Learning

Lesson study as an approach helps educators appreciate and value what students need as learners. In fact, educational values are what drive the components of planning, implementing, and reflecting during a research lesson cycle (Fujii, 2013). The concept of valuing the learner is written into the lesson plan and is reflective of the school wide research theme.

The sixth grade lesson plan written and taught by Sayuri Kasai, illustrates how teachers plan carefully, so their students will value the mathematical learning experience. For example, it states in the sixth grade lesson plan that the group considers the values of learning, so students can realize and experience math. Further, it is when students feel their questions and thoughts are valued, they in turn will value the content area. The above ideas were evident in the problem solving approach used in this lesson. For example, Fujii states that "considering the value of a task used in a structured problem-solving lesson is a critical factor in lesson study (Fujii, 2013)." Therefore, the idea of *kyouzai kenkyuu* re-surfaces in that how the teacher proceeds in choosing the task is a core factor in helping children value the subject area of mathematics.

In the sixth grade lesson I observed how Sayuri Kasai used language so students would value the task of calculating and dividing fractions. The teacher posed questions in a way that let students know she was invested in their learning. In turn, the students were enthusiastic to complete the math task at hand, which was seen in the discussion about what the '½' in the answer 7½ meant. The teacher's intentionality of choosing different examples to be used during the discussion illustrates how the teacher valued their answers since they were actual examples.

Benefits of Lesson Study

After participating in the lesson study immersion program, I learned that on the school level, lesson study will be successful if there are certain components in place. First, the school needs a leader that will help organize a Research Steering Committee (RSC), a committee that will create a theme based on a learning need. Creating a schoolwide focus/theme speaks to teachers valuing what their students already know and what more they need to learn. Also, another important feature to lesson study is the post-discussion which celebrates the important ideas that result from observing the teacher's interactions with the students.

The Japanese Course of Study outlines the importance of valuing education. Having a national expectation that students value their education reflects a healthy school system. Further, it is evident that the Japanese teachers transfer to their students they value the students as problem-solvers. This transfer creates the success of the lesson, but also creates the students' ability to revere education.

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Trinity_Thompson

The Project IMPULS trip was truly transformative for me as a teacher. There are so many best practices that can be taken away from the experience, not just in teaching mathematics but, for teaching every subject to children. One of the main takeaways I will keep with me for the rest of my career is the importance of valuing and cherishing student voices in the classroom. The classroom really should be led and directed by students and teachers should primarily aim to support student discovery in a way that results in long-term learning. There were three main ways I saw teachers succeed at doing this:

1) Asking thoughtful open-ended questions that set up students to both think flexibly about math and encourage them to explain their reasoning in order to back up their problem-solving strategy. Teachers did not do much explaining of strategies or summarizing student thinking. Instead, they moved the lesson along by continuing to question which really gave rise to student voice.
2) Having students build upon each other's reasoning. When one students though or idea is up, teachers could choose to explain their strategy or have that student explain the strategy. Instead, I often saw teachers ask other classmates to interpret their friends' ideas and to build upon them, further encouraging active engagement as well as communication between students instead of communication between student and teacher.
3) Teaching students to think of ways to visually represent their thinking so that it is clear and concise for their audience. Often, students who finished early were asked to think of ways to share their ideas with their classmates so that it would be clear. Instead of just having number sentences on their paper, students were encouraged to draw pictures or diagrams to represent their ideas and that gave birth to conversation due to possible multiple interpretations of pictures.

I will try to remind myself to use these strategies in my classroom as much as possible in mathematics and whenever possible in other subjects as well.

Another major reflection I have now is how thoughtful lesson planning for a research lesson is, especially when introducing a difficult concept to students. Obviously research lessons do not happen all of the time but this is really the way that planning should go for just about any topic that teachers know will be very difficult for students to master. I personally can think of skills that students need to master in my grade that they struggle to comprehend every year. I want to be very purposeful about planning for those skills this year.

In the past I have allowed for us to go over those concepts for longer periods of time in the school year, and to continuously return to those skills throughout the year. Those may be important for students. But I have never thought about the significance of how each topic is first introduced to students and making sure that they really discover and understand the concept behind the skill they are practicing as the unit continues. I believe this is a huge gap in teaching mathematics in the United States as it currently exists. But now that I have seen the impact of intentionally planning the introduction or launch of a unit in Japan, I know that this will be a big focus for me this coming year.

In order to do this, a lot of thought needs to be put into creating the perfect problem for students to solve. A great problem not only allows for multiple ways/strategies for solving a problem, but also is purposefully crafted to highlight and challenge possible misconceptions that may arise for students. There is a difference between introducing addition with regrouping using 9+4 versus 8+5, and it is imperative that teachers have the foundational mathematical knowledge to know that difference and apply it when planning lessons.

Additionally, follow-up lessons and problems need to written in a way that solidifies best practices by narrowing which strategy will work best across scenarios to solve problems, instead of just telling students what the best way to solve a problem is. I want to make sure that I am planning problems this thoughtfully and making the problem work for the class not the class work for the problem. It may be easy to say that this is important to do well. But this brings up another major action item I have set for myself this coming year as a teacher of mathematics: teachers must know different math curriculums and how they introduce topics. They also must know what standards/curricula are covered in each year so they have a strong sense of what has been covered in the past and what skills will be first introduced to their students.

After one of our research lesson observations, the "knowledgeable other" explained to us that every other math curriculum in Japan uses the problem 72/3 as their problem to help students think of methods for calculation. When thinking about the best way to teach partitive division or any research lesson, he suggests comparing and contrasting textbooks. If there are major trends, there may be a very good reason for this. Additionally, he reminded us the importance of knowing what comes before a lesson, even in units in previous years, so that when you choose to highlight different strategies from students, you are able to highlight ones that connect to students' previous learning, and the build upon that. Finally, he told us that knowing what comes after a lesson in the unit is helpful to allow you to know what key takeaways students need after the lesson taught on each day, and which concepts you can leave students grappling with because they will be touched upon in the future.

Looking forward, I will try my best to make sure I do this work when I am teaching. It is not okay to plan or teach concepts in isolation when there is a world of knowledge out there to gain from. Obviously there are many more different kinds of math curriculum in the United States to choose from. However, the deep dive of really analyzing a unit- how different curricula choose to teach it, what units/skills taught previously inform the lesson, and what key takeaways students need at the end of each day- is incredibly important. As a main takeaway, I know that I cannot do this all my own. I'd like to work toward vertical planning by working with teachers from other grades at my school to begin this work.

Summary

I know that for many of the participants of the Project IMPULS program, we see the successful implementation of lesson study at our schools as the best way we can share both the knowledge and resources we were privileged enough to have poured into us throughout the last week. I have reflected since I have left Japan mostly on how to make a research lesson as effective as possible in the States. That said, I find myself very interested in the best way to handle some of the logistics of lesson study and reflecting on how to implement a lesson study cycle effectively. Here are some of my thoughts:

- In order for lesson study to be effective, it needs to be something that the WHOLE school is behind and invested in and that is going to have to start from **school leadership understanding and supporting its model.** I need to work with my principal and academic directors to expose them to this work immediately.
- A strong post-lesson discussion is imperative for teacher development. This is dependent largely on the knowledgeable other. We need to **find and nurture relationships with strong knowledgeable others** in our area. During some post lesson discussions, the **principal explicitly asked the knowledgeable others to address certain topics** that teachers were still struggling to understand or wanted more strategies to use.
- **Providing and encouraging the use of technology in their school**: IPads and the use of other technology really aided academic learning and assessment by

allowing ALL students to represent what they were thinking and contribute to the lesson. They also demonstrated their learning by using it for the follow-up problem.

- **Assign a scribe for research lesson:** Research lesson notes (teacher words and student work) were typed up and shared with faculty and knowledgeable others before post-lesson discussion
- **Assign focus students for observation:** Teachers were made to observe certain students in the class so that they had people to share about all students
- **Summary:** Facilitator chose and reported out about elements that the school would focus on moving forward and how they would utilize their learning process.

I shared my these takeaways with my new principal this year because my experience was so formative for me and I wanted to make sure that I could and would be held accountable for using it wisely in my schools. Because the school was disappointed with their test results last year, he has seemed very receptive to my ideas and many new ways of thinking about teaching mathematics. He agreed to sit with me next month to think about how we can utilize some of my learnings in our middle school. I am hopeful for the work moving forward and its ability to get quantitative results, as well as nurture student voices.

Bob Sawyer

This reflective journal summaries my current understanding of Lesson Study formed from my UK and Japanese experience and associated reading which then leads on to some observations about Lesson Study and finally poses three key questions that I intend to explore further as part of my ongoing development work in the UK.

The process of Japanese Lesson Study is well documented. From the array of research articles and publications there is little doubt that Lesson Study can be described as 'the purest form of Continuing Professional Development' that engages the whole learning community. An important feature of the process is the way in which the components of Lesson Study 'synchronise' the learning.

A key role in Lesson Study is that of the 'Koshi' (learned friend or knowledgeable other). According to some descriptions of Lesson Study this person is involved in all phases of the process however in this critique the author has concluded that the role does not extend to the contribution of the planning team as defined in some articles. My experience is that whilst the koshi supports the initial thinking they are not directly involved in the subsequent planning.

It is clear though that the koshi should also be a person who has studied children's learning in mathematics for some years, gaining significant breadth and depth of experience through practice and research which they can share with the planning team. Not only will they have their own existing thinking readily available to them, but they will have some knowledge about where/how to look to mine the education literature for relevant wisdom from previous inquiries.

Each Lesson Study has a research focus that is usually described in the form of a question. It is not usually the case that Lesson Study is used to evaluate an existing method or agreed appraoch.

An individual lesson study has three basic phases: a planning phase, the research lesson and the post lesson discussion. Whilst there are key members in each part of the process is it important that the 'learning community' is involved in all of the phases.

The planning phase comprises a team of people including the koshi. This team will work over a period of time to develop the plan that is to be taught by a member of the team. The role of the

koshi in this phase is to provide research information and personal knowledge of the issues that will be pertinent to the lesson. They may do this by first sharing with the planning team information and experiences that will enable the planning team to form their own thoughts and ideas. The koshi should not become a member of the planning team as it is possible that their views and opinions will skew the lesson towards a particular style or approach.

The lesson plan will detail the precise actions of the teacher including explanations of how any resources will be used. As with any planning process the team will presume a level of prior knowledge and understanding. A crucial part of the lesson planning process is the consideration of anticipated responses from the children as a result of their involvement in the lesson. Spending time on this thinking is of great value especially in the area of likely misconceptions or barriers to learning. The anticipated responses are documented and so are the agreed actions and responses to be carried out by the teacher in the event of a misconception being raised in the lesson. In addition the lesson plan will give consideration to the research question and will highlight at various points where in the lesson the research question is being explored.

This type of planning produces a detailed lesson plan that is often quite lengthy. Once the lesson plan has been written it will be shared with all who intend to observe the lesson. Immediately before the research lesson the koshi, as well as all observers, avoid sharing their thoughts on the lesson plan, in case this alarms the teacher or pre-judges what will happen.

The lesson is then taught by a member of the team. It is important that wherever possible that the teacher sticks to the lesson as planned (the exception to this would be when an event arises in the lesson that has not been anticipated, and therefore planned for).

In England the observation of lessons is very often concerned with the relationships between the pupil and the teacher and judgements are made that relate to the 'character' or personality of the teacher to be able to form the positive relationships required to engage the children in the lesson. In Japan the view is that the engagement will take place if the lesson is of the correct form. This means that the main prerequisite for the teacher delivering the lesson is that they have the skills and subject knowledge to deliver the lesson that has been planned.

The observation of the lesson will normally be carried out by a larger number of observers. Observers will watch the lesson from either the inside or outside. Those that observe inside the lesson have the opportunity to go 'into' the class to hear the comments of specific pupils and to observe closely their work in response to the lesson. The koshi always is part of the inside observers. Many of the inside observers now use an app called 'Lesson Note' to record children's work and the work of the teacher on the board. Those observing from the outside are able to focus on the actions of the teacher and the general or 'global' response from the children. It is important that all observers confine their role to observing as any questioning of the children could lead to inadvertent support or confusion.

At the end of the lesson the post-lesson discussion takes place. This usually begins with some reflection from the teacher on how well the lesson went in terms of what the team had planned. Questions from the observers are then taken and are answered either by the teacher or the planning team. At this point the koshi does not take part in the discussion and listens quietly to the issues being raised in order to assimilate their own observations with the salient points form the post lesson discussion.

The koshi speaks only at the end of the discussion and aims to raise points that are of central importance to the research question and the design of the lesson.

The koshi is not primarily a summariser, nor is he or she the 'judge' of the 'success' of the lesson. The koshi's job is to deepen the thinking of participants with respect to the key research issue being studied, drawing on knowledge that is not available to most of the teachers present. Most of the discussion will have been about specific instances during the lesson. The koshi will draw out the most important of these and relate them to the success of the lesson.

The koshi will seek to have participants leave the discussion room with key questions in mind which they will want to go away to consider and discuss further with colleagues. The koshi might

suggest one or two relevant articles from the mathematics education literature that brings some light to the discussions. After the lesson and discussion have taken place, the koshi may be able to provide notes of their own for the participants to consider later. They may challenge the teacher and the planning team to take some of lessons learned into their future practice.

Some questions

Why is lesson Study so powerful?

The answer to this question is complex and cannot be answered without considering the culture from which this process was devised. Those that consider Lesson Study to be powerful do so because of the absence of any element of judgement about the performance of the teacher who taught the research lesson. Lesson Study critiques lessons, not teachers, which is one of its central strengths. This is difficult to incorporate into the English accountability framework where the focus is on improving the teacher through direct methods such as monitoring and feedback, coaching and training. The culture in Japan is to perfect the delivery of content and the development of skills. Lesson Study approaches this challenge through a 'learned collaborative' that delves deeply into the understanding of concepts, knowledge and skills and uses research and experience to anticipate and resolve barriers to learning presented by the children.

One could simply compare outcomes and it is well known and accepted that standards of achievement in Japan (in mathematics) are much higher than in the UK. However the culture of engagement and resulting expectations to achieve make a significant impact on the learning process.

Will Lesson Study have any impact in a culture of immediate response to 'requires improvement'?

I ask this question because at first sight it would seem that the UK accountability system for school improvement appears completely incompatible with the process of Lesson Study. A developing teacher in the UK who is not at the required standard (good) has only a short period of time, a matter of weeks, to improve before being placed on a 'capability programme'. These programmes do not focus in sufficient depth on the 'craft' of teaching and are too short to produce any significant gains in teacher subject knowledge. As a result it is difficult to see how Lesson Study could replace the current regime of CPD in the UK as most school leaders would not dedicate the required time for teacher development or wait for the impact of Lesson Study to take place.

However my experience of the range of teacher improvement programmes delivered by Teaching Schools to date would suggest that Lesson Study has a vital and necessary role in the development of good and outstanding teachers in the UK. For me a crucial component of Lesson Study is the planning phase. To provide all teachers with the opportunity to explore an aspect of mathematics by considering the relevant research and current professional thinking which is then built on through collaborative planning has to be a great value (and indeed in my view a professional duty of all teachers). Importantly within the planning phase is the development and treatment of 'anticipated pupil responses' that I believe to be very powerful. In the UK teachers only learn to deal with the responses of pupils by trail and improvement. In other words they often only experience a thought or an idea from a child as it happens in the lesson and because of the nature of the lesson they have very little time to be able to think about how to manage and build upon such responses. In Japanese Lesson Study the panning team spend a considerable amount of time not only thinking about the anticipated responses but by also 'engineering' particular responses through the careful design of problems and activities.

Can Lesson study be augmented?

The short answer to this question is 'NO'. However this is a really important question as the answer to this is shaping the use of Lesson Study in the UK. Currently in the British system there is an increasing use of 'Teacher Research Groups' (TRGs) which utilises components of Japanese

Lesson Study. A typically TRG has a planning component, a lesson observation and a feedback session. However in the vast majority of these the planning process is cursory and takes place in an afternoon. It does not require the planning team to consider current and relevant research nor does it include the key person 'Koshi'. The lesson observation is not precise and is often 'contaminated' by the observers who interact with the pupils and finally the post lesson discussion does not have sufficient depth and enquiry to conclude how effective the lesson was.
In my view Japanese Lesson Study cannot be changed.
I have also considered whether the addition of 'pupil voice' (feedback form the pupils about their view of the lesson) would improve the effectiveness of Lesson Study as this is a feature that is not currently included in Japanese Lesson Study. Whilst I am currently uncertain my initial thinking is that the precision and form of Japanese Lesson study would not benefit from the inclusion of pupil voice. There are several reasons for this. Firstly the data from pupil voice tends to be subjective and often relates to how much the pupils enjoyed the lesson. In Japanese Lesson Study this information is evident from the lesson observation where the observations focus on how the pupils are responding and learning to the lesson. Secondly collating information from 30 pupils about challenges in learning would not necessarily reveal how the lesson could be improved. In Japanese Lesson Study this information is gathered through detailed observation of the pupil's work and of their responses to the teacher in the lesson.

David Wylde

Impressions of the Japanese education system

The Japanese education system and schools are very different to what we have here in the UK. The biggest difference I found was how homogenous the schools were, mostly due to a very tightly controlled national curriculum. There are only 6 textbooks used in Japan, with 2 of them having a 70% share of the market. This effectively means 70% of Japanese students are having practically the same maths lessons and are therefore developing very similar approaches in how they solve mathematical problems.

The way Japanese students are taught using problem solving is very different to the procedural teaching I often see here in the UK. In Japan topics are often introduced using a contextual problem which students should be able to solve just by using their prior knowledge. This seems an effective way of teaching maths as the students seemed to be able to confidently make links and therefore develop a deep understanding independent of the teacher. This works so effectively because of the careful sequencing of the lessons in the textbooks, something which a lot of research and planning seems to go into.

Observations from lessons

It was fascinating watching so many Japanese lessons and I was surprised with how wrong some of my misconceptions were. Before the trip I assumed that the students would be learning by rote in silence but I was taken aback with how much they loved maths and their vocal enthusiasm during the lessons. In all lessons the teacher consciously planned to arouse the students' curiosity, especially the teacher of the "lemon lesson" who started with a mystery box where he slowly pulled his shapes from. I was also surprised by how well the Japanese teachers were able to predict the student's responses. In the several lessons I felt that I was reading a script as opposed to a research proposal.

There did however seem to be a downside to having such a detailed lesson plan and this was the lack of flexibility Japanese teachers seemed to have during the lesson. They seemed hesitant straying from the lesson plan, even when it was evident that the student's learning would suffer unless they did. I know research lessons are meant to be followed but when I asked the teacher of the division lesson what he would do in an everyday lesson, he said he would stop so he could go away and plan some more. I feel that this could be a case of the culture of lesson study negatively affecting the practice of teachers during their "normal" lessons.

However, my opinion is that overall lesson study is extremely beneficial to the Japanese teachers. After watching several lessons I have come to the conclusion that Japanese teachers are generally better at planning then UK teachers. This could be down to the careful sequencing of lessons and the mindset that competency will only come with hard work. It could also be down to the fact that often the best teachers in the UK are given more non-teaching roles which can distract them from thoroughly planning lessons. I do however feel that the UK teachers are better at adapting during the lesson to maximise student progress and have developed a better pedagogy for differentiating the work. I feel both groups of teachers have much to learn from each other.

Lesson study process

Lesson study is the main CPD for Japanese teachers and is one of only a few methods that have been showed to have a positive impact on students. The idea of working collaboratively to continually improve the practice of all those who are a part of the process would work well in any context, but what I observed seemed to fit perfectly with the Japanese culture and education system.

The key aspects of all lesson study are;

- Clear research purpose which is usually determined by a panel within the school who identify the areas of development.
- Kyouzia Kenkyu is used to careful design the resources so that they maximise the student's learning and help deepen their understanding.
- Written lesson / research proposals which read and feel quite different to a normal lesson plan.
- Live research lesson and discussion which can be attended by just the teachers in the school or by teachers across the district.
- A Knowledgeable other who not only distils the learning from the process but also gives a short presentation on the subject matter.
- Sharing of results to all those involved and making these results accessible to all.

I feel other countries usually fail to use lesson study effectively as schools do not allow enough time for the process. Unless lesson study has been engrained within the culture of a school it is also unlikely teachers will want to dedicate their limited time to it. Another danger is that without an expert, lesson study could potentially be detrimental to a teachers learning. A group of inexperienced teachers could convince each other that a poor lesson was successful and then replicate this practice in the future.

The post lesson discussion had a better structure then those I have observed in the UK. This structure allowed time for reflection, for the challenging of the lesson planning team and also the input from a respected academic. The ordering of the discussion was as follows.

1. Planning team who discuss thinking behind the plan.

2. The teacher who self reflects.
3. Others who give feedback and asked questions of the teacher.
4. Knowledgeable other who comments on the lesson and also comes with pre - determined ideas which they share with the group.

There were however slight differences between the discussions I observed. The most notable one for me was how the input from the planning team differed. I assumed that they would be just as accountable for the lesson as the teacher, however in a few lessons I observed they seemed to feature very little during the post lesson discussion.

Lesson study in my context.

I intend to use lesson study, like the Japanese, at different levels.

The first use of lesson study will be in my maths department, where we have had some limited experience so far. Having a clear research focus over the next year is a must and will really help to maximise the benefit of the process. I also want to change the types of lessons we decide to research, as it was highlighted to me that the best ones to use are those the department typically struggle to teach well. I will use the experienced teachers to take on the role of knowledgeable other when the novice ones are teaching however I also want to reach out and bring in more academics to take on this role when the experienced teachers take a lesson.

I also want to embed lesson study within the whole school so I will share my findings with all of my colleagues. However, the main problem I highlighted earlier is time so in order to overcome this I will propose 2 solutions.
1. To timetable departments in a way where they can have weekly meetings during the school day.
2. To use directed CPD time to work on lesson study.
Even with these solutions covering teachers whilst they observe the lesson will still be an issue. I propose we overcome this by splitting larger departments into smaller clusters, ensuring at least 1 of the team is an experienced teacher.

Finally, I will use my position as assistant head and ITT (initial teacher training) lead to introduce lesson study to other schools. I will personally be leading some ITT sessions within our consortium and I plan to use lesson study to help develop our trainee teachers. I will share the structure with them, give them time within the sessions to start planning, and then ensure an experienced teacher is a part of the process to help with the planning and to evaluate the lesson.

For those schools who are not a part of the consortium I will hold some research lessons at Riverside and invite the leadership team to observe them. By observing the lesson study process and hearing about my experiences I would hope that they would see the benefits of it and would want to implement it in their schools. I would have a particular focus on our new sister school which has just opened.

Derek Robinson

Background information

Although I had visited Japan twice previously on trips arranged by Professor David Burghes (Centre for Innovation in Mathematics Teaching, Plymouth University) and Professor Masataka Koyama (Hiroshima University) this was still and eye opening and breath taking experience. Consequently I would like to begin by thanking everyone involved in this project but I would like to single out Professor Akihiko Takahashi for his patience in answering our never ending questions and Sachi Hatakenaka for her constant help and advice.

Through my previous visits and ten years of being involved in Japanese Lesson Study (JLS) in the UK I had a good understanding of how JLS functions. I was also aware of how difficult it is for teachers in the UK to implement some of the big ideas involved. In particular the concept of learning through problem solving rather than reinforcing learning with problem solving. It was interesting to read how Japanese teachers "use the textbook to teach mathematics" (Takahashi, 2016) and it is through the use of these textbooks that teachers gain the necessary skills to teach through problem solving. This probably explains why the two areas that I wanted to know more about were the use of textbooks and how the children use their exercise books, as this was something I had perhaps neglected in my previous visits. Consequently I would like to begin my reflections by looking at these two areas.

Japanese textbooks

Although we did not see any pupils actually using the textbooks the comments made by Professors Takahashi and Fugii about how textbooks are used to plan lessons were very enlightening. It was encouraging to know that even in Japan new teachers struggle to develop the skills needed to teach through problem solving without strong collegial support from more experienced teachers.

In particular it was evident that the textbooks act as a major planning tool for teachers as they contain "resources to assist teachers in their instruction via problem solving and to help students to learn through problem solving" (Takahashi, 2016). Although I had looked at the textbook series, "Mathematics International" (Tokyo Shoseki) over several years, I had not fully understood how the teacher uses these textbooks in planning. I had not really grasped that most chapters begin with a "preparation" page on the left, which either covers everyday mathematics or recalls, "mathematics already studied". This is then followed by the opening problem on the right hand page. This page acts as a stimulus for the teacher's planning as it includes "a way into the question" as well as possible hints that the teacher might choose to use in his/her planning. The following pages then offer multiple approaches to solving the problem introduced by cartoonlike characters, which also includes their diagrams. All of this had been very confusing to me as, if this was the students' textbook, how did this encourage the students to "think for themselves" and "present their own solutions". As Professor Takahashi explained, although the students have these textbooks, they are not used in the lesson and students do not "look ahead" to the next lesson by turning over the page. I now understand how the textbook is designed to both assist teachers in their instruction via problem solving and to help students to learn through problem solving. It now makes sense. It also makes sense that textbooks in Japan have to be approved by the government to ensure they capture the essence of the current course of study.

Unfortunately there are no such textbooks in the UK but this trip has inspired me, in conjunction with Professor Burghes, to rewrite our current MEP textbooks in a similar style. In other words write textbooks that serve both as a teacher's guide to teaching through problem and a student's guide to learning through problem solving.

I was already aware that Japanese problem solving lessons could be described as "structured problem solving." In each lesson there is one very clear learning objective based on the course of study and that teachers are rarely, if ever, side-tracked from achieving their goal. I had probably not appreciated how carefully the scheme of work, as dictated by the textbook, helps the teacher to

plan a series of lessons where the "learning residue" (Carpenter et al., 1997) is carried forward and reinforced by using it in the next lesson. We saw many examples of lessons that made reference to and built on previously learnt concepts. In the UK, we have a history of using more open problems where the end point is not clearly defined and not everyone will reach the same point. This possibly encourages more creativity in UK classrooms but sacrifices a more disciplined approach very apparent in the Japanese classrooms. It is very clear that in Japanese classrooms the both teacher and students completely understand their roles at each stage of the lesson.

Students' notebooks

In my own school, we generally start the school year with high hopes that our students will use their notebooks productively. Initially we try to get our students to take pride in their work and follow basic rules in setting out their notebooks. I had seen in the Mathematics International textbook series that there is a much greater emphasis on a standard approach to how these notebooks should be set out. Students are expected to record the date, today's problem, the student's own idea, their friend's idea, a summary of their learning and a reflection. The reflection itself covers various questions such as, "What you've come to understand?" "What have you noticed?" "What do you want to examine next?" and "What you thought as you listened to your friends' idea?" Well that's the theory, so what did we see in the lessons we observed?

I am pleased to say we saw exactly that and yet some of it wasn't quite what I anticipated. Students in the lessons we observed tended to work alone on the problem for around 10 – 15 minutes. There was virtually no interaction between students sitting next to each other. In the UK, we generally encourage students to try the problem for themselves for a few minutes before turning to their neighbour and sharing their initial ideas. Problems are frequently tackled in pairs with different pairs offering different solutions. It is rare for the pair to offer individual solutions as they generally reach a consensus before offering their solution to their teacher. I had assumed that Japanese students worked alone and then shared solutions with their friend. I had assumed they then recorded their friend's solution in their notebooks. This is not the case.

During the "kikan-shido" phase of the lesson, the teacher circulates around the room noting which methods of solution each student has attempted and deciding whom he will invite to present their solution during the "neriage" phase. It only after the whole class discussion ends that the students choose which of their friends' solutions they will record in their books. It is clear that in Japanese classrooms everyone is regarded as a friend and so the students are free to record the solution that interested them most. This is frequently not the case in the UK where there are classrooms are often dominated by various cliques and students work within these confines.

It is very clear that Japanese students take immense pride in their notebooks and all of the books I was able to see were immaculate. It is also clear that the use of notebooks is consistent across all years and that the students understand exactly what is expected of them.

Other interesting points

Over the past ten years we have relied heavily on the "APEC guide to planning and analysing lessons" in our own planning. Consequently I was very interested to see if the lessons we observed followed their commended approach. In general they did but there were some inconsistencies. In particular with the sections entitled, "Providing meaningful tasks or problems" and "Anticipating and planning for students' difficulties".

Providing meaningful tasks or problems

One of the lessons from the APEC Lesson Study site that we have continually used in training teachers in the UK is Mr Hase's lesson, "Do I Have a Window Seat or an Aisle Seat?" We use it specifically to highlight how Mr Hase uses the students' sense of curiosity and surprise to captivate his students. Imagine my delight then when watching our first lesson, "What is the size of the shaded part?" to not only recognise M Hase's influence in Mr Nakayama's teaching but also to see

Mr Hase himself observing.
In his lesson plan, Mr Nakayama referred to "interest, eagerness and attitude" something we have also been working on in my own school largely thnks to Mr Hase's influence. In this lesson Mr Nakayama made use of a "mystery box" in exactly the same way as did Mr Hase in his lesson. This clearly hooked his students into the lesson. They really wanted to know what would come out next.
Unfortunately in the other lessons we observed, no one else seemed to have spent as much time thinking about how the problem would "capture their students' attention". Many of the problems were presented exactly as the textbook suggests which seems to imply that "paying attention to students' sense of curiosity" was largely ignored. It was clear in many of the other lessons we watched this could have been easily rectified. I think this is an area for Japanese teachers to revisit.

Anticipating and planning for students' difficulties

Just as in Mr Hase's lesson, the students had a few minutes on the task before Mr Nakayama called on any students who could not get started to join him at the front where he had carefully prepared resources to prompt their thinking. He did not tell them what to do but by intelligent use of questions and pictures spurred the students into action. I do, however, have some concerns about this approach being continually adopted in lessons. It could well be that some students may come to rely on the extra support if they know it is always coming and consequently they may not try to solve the question for themselves.
As a final point in this section, I refer to Mr Hase's lesson as his teaching style has clearly influenced other teachers at Sugekari Elementary School, demonstrating the usefulness of sharing good practice within a school through lesson study as well as the value of the APEC site.

Final points

This trip differed from my two previous visits in several ways. In Hiroshima, as we did this time, we observed several lessons and listened to the post lesson discussions. One big advantage this time was Tad's unobtrusive on-going translation of both the lesson and the discussion. This was invaluable in improving my understanding of some of the finer points of both. Unfortunately in this trip we did not have as many opportunities to talk to the teacher after the lesson and ask our own questions. This is a (small) negative point.
The other positive differences were the chance to have informal discussions with a variety of teachers from across the world all of whom brought different experiences and views to the table. This was most helpful. Finally there were the orchestrated discussion led by Professors Takahashi and Fugii. Their expertise was very evident and most enlightening.

Jan Parry

Mathematics Teaching and learning in Japan and Japanese Lesson Study

Having had some time to reflect on my experiences in Japan I will draw together some of my impressions but, as I have found over the last month, whenever I talk about, or discuss, the lesson study I saw in Japan I find I emphasise different aspects of the lessons or the process each time. So with one eye, as always, on how I can use my experiences with the lesson study clusters I work with, in both the Primary and Secondary sector, I will share my thoughts.
Firstly I was really struck with the relationships between teacher and students. The students trusted their teacher to guide them into the mathematics being covered with relevant examples and then give them the opportunity to explore different ideas; the teachers drew out a variety of ideas

and thoughts from the students during the lesson which in turn helped them to find solutions to the problem posed. The nurturing of the individuals within the class was most evident with the youngest grades, the teacher slowly building up their confidence to speak about their thoughts; they talked to each other about their ideas, recorded solutions in their books and felt supported if they made mistakes or had misconceptions.

The extent of the focus on problem solving in Japan surprised me and as the week went on I began to really appreciate the differences between teaching concepts through problem solving and teaching the processes of problem solving so that students are able to access solutions to problems in a multitude of scenarios. So to teaching concepts through problem solving, I was impressed with the way that the majority of the students were able to think about solving a problem in a variety of ways. Many of the students were confident of their ideas, able to articulate them and the mathematical expressions / equations accurately alongside the visual representation of the solution. Some of the teachers were extremely competent in asking probing questions that made the students check their thinking and help them move on. The board work created in each of the lessons was produced by both the teacher and students, on one occasion a student showed a solution visually whilst a second was asked to write the mathematical equations that supported the solution. This was followed by the reverse with a student writing a different set of equations and another asked to show what this looked like visually. This board work was support for those that had not found all the strategies and for others to check their methods, equations and solutions. The written work in the student's book was clear and concise and allowed the teacher to check their depth of understanding of the concept being covered.

Throughout the week my concerns about the teaching and learning methods used were similar in each of the lessons seen. I was increasingly aware that although the lesson plans talked of concrete examples, manipulatives, we saw very few of these being used and those we did see were in the teachers hands not the students. In each of the lessons there were some students who were not able to access the learning at the point of entry from the teacher and yet very few were offered manipulatives to support them. Ongoing assessment for learning that responds to a student within the lesson did not appear to always happen, we saw one teacher respond by asking a group of students to join him for further discussions at the front of the class but little else. As the week went on my focus when in the lessons went from those that were involved and learning to those who appeared to have difficulty in accessing the learning. Although each lesson recapped on prior learning some students were still not ready for the particular concept being covered. The students however rarely asked for support and appeared to try and work with those next to them to get something in their books. Was their self-discipline because the adults in the room outnumbered the students or do they remain cooperative however many lessons they find difficult to access? Where does formative assessment and, more importantly, response to it sit with this whole class teaching and learning? In some lessons teachers drew ideas and suggestions from many of the class but in others only a few students were asked and these students were those that had the predetermined strategies laid out in the lesson plans. Lastly the very structured lesson plans with anticipated responses/strategies felt at times like a restraint on students; in the lessons seen they did not explore the concepts outside of these and at times it felt very formulaic. Teaching concepts through problem solving I can now appreciate gives many students the structures and strategies to be able to see solutions in a variety of ways and gives them the confidence to manipulate mathematical equations with ease however if the students are not able to explore a route that has not be anticipated then does this really prepare them for the world where many of the problems to be solved have yet to be discovered?

I am privileged to have seen lesson study in Japan, it is so embedded in the education system and has so many obvious benefits. I loved the fact that districts, schools and groups of teachers all come together many times in a year to discuss learning. I experienced many of the positive characteristics; the shared commitment to teaching and learning, the nurturing of the students throughout their schooling, the determination that learning is a pleasurable experience. The

aspects that most struck me and that I will be trying to explore with my groups are; the relationship between the teaching and learning, the research into the curriculum materials and text books, and the role of the 'knowledgeable other'. We have tended to concentrate on observing characteristics and behaviours around how students learn strategies to problem solve, in Japan the post lesson discussion went beyond recalling student responses to thinking about the teaching actions that brought about those responses. We saw how one problem was introduced each lesson but, particularly with the division lesson, how this problem followed on from work done in previous lessons or even the year before so that students had to really think about the sameness and differences in the progression of concepts. The importance of the input of the external 'knowledgeable other' was highlighted after this particular division lesson as the planning team had not appreciated the significance of the step involved between the previous year's lesson and the one we saw. The curriculum knowledge and pedagogical expertise was excellent and informative to listen to and from the reaction of the school will really move them on in their thinking and planning around even the simplest of concepts.

This all brings me to my thoughts and this is one I cannot really square in my mind. The teachers, schools and districts really invest significant time in planning and delivering the lesson study research lessons, experts research the ideas for the text books and yet it is really unclear to me how the feedback from a research lesson is used to support the teachers and schools improve their pedagogical strategies. What are the follow up procedures? What support do the teachers and/or schools get if specific questions have been raised? What other professional development is provided alongside the lesson study? When do they have the opportunity to develop/adapt day to day pedagogical practices?

I feel very honoured to have taken part in this year's IMPULS immersion programme. I really enjoyed visiting all the schools and seeing the lessons. Having ten days to meet with colleagues from around the world, to listen to and discuss aspects of lesson study from different experiences was brilliant and has certainly made me think more deeply about the work I do with lesson study here in England. Thank you very much for the experience.

Pauline Tyson

IMPULS; through the window and in the mirror *Immersion in Japanese Lesson Study; observations and implications*

There are two major and very different aspects of the IMPULS immersions programme; Japanese lesson study and Japanese style of mathematics teaching (problem solving and reasoning). For each of these there are two areas for discussion. Careful observation of practice within the context is, of course, very important. But perhaps more important is reflection on the implications for application within my own practice, and, indeed, for practice throughout the United Kingdom. The first of these is rather like looking through a window, the second more akin to looking in a mirror.

It was a great privilege to have the opportunity to experience and observe the every-day operation of lesson study in a variety of schools, and it was heartening to note that these were not 'show schools', as no two lessons and post lesson observations were the same, and none reflected the theory of a perfect lesson study cycle. For example, one observed lesson corresponded exactly with the plan for that lesson, observing teachers seemed to be focussed on the learning that was taking place, and the post lesson discussion concentrated on what could be learned for future practice.

However, the 'Koshi', a previous head teacher of the school, did not seem, from my perspective, to add to the discussion or lift it to a 'higher level' in any way. Another lesson, however, deviated from the plan, and did not appear to achieve its objective. The post lesson discussion had a negative and critical feel to it, but the 'Koshi' refocused the discussion and brought in some new information which really did seem to lift the discussion to a higher level.

Looking 'through the window', a number of elements were striking. Teachers are engaged in lesson study from their first experiences in school during training, and are therefore familiar with the conventions – how to observe a research lesson, how to engage in post-lesson discussion, for example. So by the time they are fully qualified, the lesson study cycles are almost 'second nature'. Closely related to this is the fact that lesson study appears to be the only (or certainly the major) form of CPD within Japanese schools, and therefore has significance. The high profile of the lesson study research cycle also seems to lead to the expectation that teachers will continue to learn after they have qualified – in fact, it was clearly stated that a teacher is considered to be a 'novice' for at least the first six years after training. Teaching is considered to be a craft which one continues to develop, practice and improve. Each cycle builds on the previous one, as the theme was school-wide, and is maintained for at least two years.

'Through the window', the presence of all members of staff in both the research lesson and the post lesson discussion had real potential to lead to staff cohesion and a comprehensive understanding of progression of the research topic through the school. There also appears to be a deep sense of mutual respect – perhaps born out of the fact that all members of staff will, at some point, be the teacher taking the lesson. Or perhaps it is because members of staff are aware that the lesson has been thoroughly researched. Or perhaps it is deeper than that; there does seem to be a deep sense of respect for both other adults and for children amongst the Japanese community as a whole.

Although it was not practical because of time constraints, it was a shame that we were unable to see the whole lesson study process, as one of the significant identifying elements of the Japanese form of lesson study is the detailed research into the topic of the lesson. It would have been good to see the process which took place, how the teachers involved engaged in the research, how much time was spent on this valuable element. Were different aspects of the research undertaken by different teachers, did they all research the same elements and compare notes, or perhaps was one teacher responsible for the main part of the research? Observing these practices may have helped with my consideration of the 'in the mirror' part of my reflection.

My personal experience of lesson study prior to the immersion programme has followed the format advocated in Dudley's (2008) *Improving practice and progression through lesson study.* Two or three teachers from different schools meet, decide on a focus, plan a lesson together, one of the teachers teach the lesson. The other teachers observe three pupils each carefully throughout the lesson to determine the effect of the teaching on the learning (concentrate on the learning and the teaching will improve). These three pupils are then interviewed to establish their view of the learning. A post lesson discussion between the participating teachers ensues. Amendments are made to the lesson, and another teacher from the group teaches the amended lesson to another class. Theoretically the findings are shared with the rest of the staff in each of the schools.

Although there are clearly similarities between the models, perhaps key differences are as follows:

- Time is allocated for research into the lesson (up to five weeks of research prior to planning the lesson as opposed to one afternoon for research and planning of the lesson)
- The lesson study focus is a shared whole school focus, as opposed to a stand-alone focus chosen between the three participants
- The research cycle is prepared and worked on by a team of teachers from one setting as opposed to teachers getting together from different schools
- All members of staff are present for the research lesson and the post-lesson discussion
- Lesson study research cycles have a high status in the school, all teachers are involved in a cycle at some point in the year as opposed to a small handful of teachers opting to get together to have a go at lesson study

- Lesson study is THE form of CPD as opposed to being a 'bolt-on' within an ad-hoc provision of CPD which may incorporate whole-school training or teachers being sent on courses at the discretion of the head teacher
- There is a 'knowledgeable other' involved within the research cycle whose role is to lift the discussion to a higher level so everybody learns something new from each cycle
- There is a culture of continued learning within the teaching community, new teachers are considered to be novices as opposed to the expectation that a teacher will be an expert on graduation from training
- The focus is on improving teaching and learning as opposed to observation of teachers for performance management or judgemental purposes
- There is no OFSTED or judgement of a school as 'failing' or 'outstanding' dependent on the results of a two day inspection process or test results
- The Japanese model does not usually require observers to focus on individual pupils

Within the last month, a new guide for CPD has been released by the Department for Education in England (July 2016). All four elements of the guidance provide justification for introducing a culture of research lesson cycles as a school's main form of CPD. The guidance suggests that professional development should consist of coherent programmes which are sustained over time, with a clear focus on improving pupil outcomes. This provides a strong argument for using the school's development plan as a clear focus for research lesson cycles in the school, as each cycle could build on lessons learned in the previous cycle, providing both coherence and sustainability. It also tends to suggest that incorporating Dudley (2008)'s principle of focussing on pupil learning and interviewing pupils after the lesson could be a useful addition to the Japanese model. The guidance states that professional development should be underpinned by robust evidence and expertise; clear justification for introducing the role of the 'knowledgeable other' (Koshi). Professional development should, according to the guidance, also include collaboration and expert challenge. One of the strengths of the Japanese model is the strong emphasis on collaboration achieved through whole school involvement in the research lesson. And, again, the role of the Koshi is to provide that important element of expert challenge. In itself this document seems to provide justification for beginning to work with school to introduce this highly effective form of professional development. However, there are significant barriers to success.

Although the UK government advocates collaborative, sustained professional development which is underpinned by robust evidence and expertise, no financial support is to be provided. Within a framework where teachers have very little preparation time, considering strategies to release a group of teachers to undertake research is a challenge. In addition to this, it is not clear when the research lesson could take place in order for all members of staff to be present – pupils in England may be unwilling to stay after school or return to school on a Saturday, and schools will be unwilling to provide cover for other classes while the teachers are observing the lesson. Another significant challenge is the supply of a Koshi. Many schools are struggling financially, and may not see the benefit of buying in a specialist 'knowledgeable other'. Until there is clear evidence that overcoming these challenges is worthwhile, it will be difficult to encourage schools to 'buy into' the concept. In addition to this, there is a strong culture of observation for judgement within the English education system, and many teachers are reluctant to allow others to observe their lesson for fear of negative feedback. A culture of collaborative working and mutual support could take time to develop.

In light of these considerations, looking 'in the mirror', the institution where I am employed is planning to run two or three pilot projects in local primary schools over the next year, training whole school staff the main principles of the research lesson cycle, working with the staff throughout the year as they engage in repeated lesson study cycles, developing a culture of constructive lesson observation and post lesson discussion, providing the Koshi from the University staff. The process will be subject to rigorous research, and data will be produced at the end of the year, in the confident belief that the effectiveness will be self-evident. Towards the end of the year it

is hoped that the schools will feel confident to hold open research lessons for other schools that may be interesting in developing lesson study in their own learning communities.

The second aspect of the immersion programme focusses around the style of lessons.

As an outside observer, three points stood out. Firstly, every part of each lesson is intentional. The research which precedes the lesson clearly results in a carefully constructed progression with carefully chosen examples. Secondly, for each lesson, student responses are anticipated, and in each lesson that was observed, every one of those anticipated responses was seen. Thirdly, although the majority of the children were engaged at all times during the observed lessons, it was interesting to note that low level disruption was ignored, and in some lessons, notably in the lower grades, there were some pupils who did not appear to join in with the lesson at all. I would really like to observe a series of lessons to see whether these children did, in fact, develop understanding of the concept by the end of the unit of work.

It is interesting that within this lesson format, problem solving skills and mathematical content are taught together, which appears to conflict with a popular line of academic thinking which suggests that children need to develop problem solving and reasoning skills through discrete teaching. It is also interesting that, in the lessons observed during the IMPULS programme, there was limited collaboration, surprising given the bank of evidence suggesting the value of talk and peer support. Additionally,it was surprising that, although within the research part of the lesson plan, reference was made to the importance of concrete, pictorial and abstract representation, very little use of physical equipment was observed, even within the First Grade lesson.

Looking 'in the mirror', there are a number of similarities with the 'mastery' approach to learning mathematics currently being advocated by the Department for Education in England following the government-funded two year Shanghai/England Exchange and High Quality Textbook Projects. Perhaps a key similarity is the amount of research that precedes the development of the textbooks and the delivery of the lessons. In Japan each of the examples in the textbook are intentionally chosen and refined as a result of continual review following lesson study result analysis. In Shanghai, teachers of mathematics are mathematics specialists, and spend a considerable amount of time observing and learning from other teachers' practice. When it comes to implementation in England, the concern is that this research element may not be transferred across, and that the essential element of continued professional development to ensure secure teacher subject knowledge may not be provided. The general pattern of the Japanese and Shanghai lessons is also similar, with clear principles of building in small steps on previous knowledge, taking one key concept per lesson, working through this in detail and discussing possibilities for generalisation, summarised, perhaps, by the phrase 'teach less, learn more'. In both settings there is also an understanding that there is no such thing as 'giftedness' in mathematics, and the general assumption that all will learn the concept, although some may choose more efficient strategies. This is a very difficult concept for teachers in English primary schools to grasp, possibly as a result of the influence of National Strategies with which the majority of schools have been working, which strongly advocated differentiation by task, albeit within flexible groupings Many teachers still have the belief that unless the class is divided into attainment groups, with different work provided for each group, the teacher has failed to cater for all the pupils in their class.

What are the implications for my practice? I was impressed with the engagement, confidence and enthusiasm displayed by the pupils, and facility with which they were able to both make connections with past learning and explain their new learning. I was also impressed with the '*neriage*' part of the lesson, but am acutely aware of the fact that, although the teachers made this look easy, it was the result of much training and in depth research. As a teacher trainer and CPD provider, perhaps it is here that I need to focus my efforts. How do I equip trainee and in-post teachers to lead and support pupils through this important part of the lesson; what are the key elements that avoid it becoming a 'show and tell'? This demands more research on my part.

Through the window and in the mirror, the IMPULS immersion programme has been an invaluable addition to my learning journey, for which I am very grateful. Observing successful practice in a

different cultural setting and reflecting on the implications for practice has enabled me to engage in deep analytical thinking about effective forms of continued professional development and pedagogy for the teaching and learning of mathematics. This learning journey will continue as I dig deeper into some of the unanswered questions regarding adaptation to allow for cultural differences whilst ensuring preservation of key elements of what has clearly been a highly successful practice for a good number of years within Japanese educational settings.

Sheila Evans

Whether observing lessons, participating in post-lesson discussions and workshops, or informally chatting to colleagues, different aspects of my understanding of teaching and learning were 'shook' over the course of the program. Here I've selected just three: the Neriage, the post lesson discussion, and what it means to problem solve. These three themes connect to my own research work in the UK and I hope also will be of interest to the reader.

I would first like to briefly describe my view on how specific, distinct qualities within the Japanese culture weave through the structure and content of lesson study in a way that is different from my own experiences of mathematics education. Japanese teachers and students [and possibly parents also] appear to share a commitment to the same long term learning goals. Threading through these shared goals is the culture of joint responsibility towards achieving them. I think it is the *mutuality* of endeavour that engenders a sense of the importance both of what is being studied by students and the teacher's role in this activity. This in turn may foster the belief that all will work hard to achieve these joint goals. This was evidenced, for example, in the complete absence in all observed lessons of students being 'told off'. The primacy of striving to improve by working hard may exist in UK classrooms, but I think compared to the Japanese, teacher and students in the UK, not only focus on the process of improvement, but also on their perceived current position relative to peers' performance, and the amount of effort they have expended in order to arrive at their position of understanding. If they consider this position is not a great one to be at, then this may impinge negatively on a their motivation to work hard. In other words a fixed mind-set may be more prevalent in the UK. Moreover, there is much research to indicate student and teacher's in the UK often do not share the same learning goals. These factors I believe should be carefully considered when implementing lesson study in the UK.

The Neriage: Whole class discussions

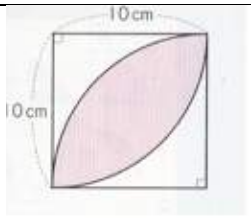
I am particularly interested in the Neriage component of a lesson in which the teacher orchestrates a whole class discussion. It is, I believe considered to be the most crucial stage of the lesson. As Akhito Takahashi stated on the first day of the program, it refers to kneading or polishing in pottery, where different colours of clay are blended together. This serves as a metaphor for the considering and blending of students' own approaches to solving a mathematics problem. Moreover, it provides an opportunity for teacher and student to together model how students should communicate mathematics both orally and through writing work.

During the course we witnessed great skills on the part of teachers, as she/he selected student work carefully and sequenced the work in a way that elicited the most profitable discussions. Explicitly comparing and connecting worked-out solutions is consistently evidenced in the research literature as being productive pedagogical strategy. For example, two large international TIMMS studies

(Trends in International Mathematics and Science Study, 1995 and 1999) investigated the common features of the teaching in the countries of high-achieving students. Researchers noted differences such as, whether the teacher lectured students or emphasized group work, or whether the problems set were embedded in a real-world context or dealt solely in abstract mathematics, and so on. They found none of these variations appeared to determine student outcomes. After further analysis of the data, researchers concluded that a defining factor was the opportunities for students to make explicit connections among mathematics (Stigler & Hiebert, 1999), (Gonzales et al., 2008; Hiebert et al., 2003).

By way of exemplification I will now describe how the Neriage was enacted in a lesson I observed: The student task was:

What is the area of colored region?



The solutions below represent the one's the teacher(s) had figured out (with the help of a text book) students may use. These did indeed arise in student solutions and were used in the Neriage, in the order presented here, albeit all aligned horizontally on the board.

① □ – ¼ circle × 2

10 × 10 = 100

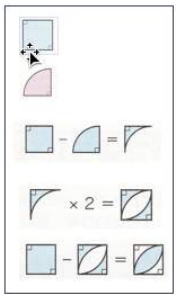
10 × 10 x 3.14 ÷ 4 = 78.5

100 - 78.5 = 21.5

21.5 × 2 = 43

100 - 43 = 57

Answer 57 cm²



② (¼ circle – ◿) × 2

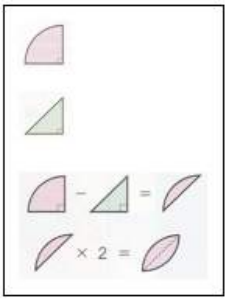
10 × 10 x 3.14 ÷ 4 = 78.5

10 × 10 ÷ 2 = 50

78.5 - 50 = 28.5

28.5 × 2 = 57

Answer 57 cm²



③ ¼ circle + ¼ circle – □

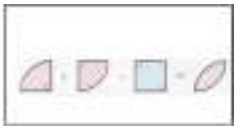
10 × 10 x 3.14 ÷ 4 = 78.5

78.5 + 78.5 = 157

10 × 10 = 100

157 - 100 = 57

Answer 57 cm²



56t

Teacher learning through post lesson discussion

We observed several post lesson discussions orchestrated by the team of teachers who devised the lesson. In these cases the teacher did not simply ask the observers for comments about the lesson and suggestions for improvements. Their questions appeared to be framed around the research question for the lesson, clearly focusing on ways student learning may be improved.

However, at times during some discussions the teacher(s) were faced with a barrage of criticism that I felt could potentially undermine their self-efficacy as teachers and ultimately deter them from participating in lesson study. However, the Japanese culture of focusing on just the process of

self-improvement rather than also on where their teaching is currently positioned within this process, may alleviate this issue. Although clearly this is speculation, I think I will need to carefully, and sensitively consider how to support these discussions to help ensure lesson study works within the environment I am familiar with.

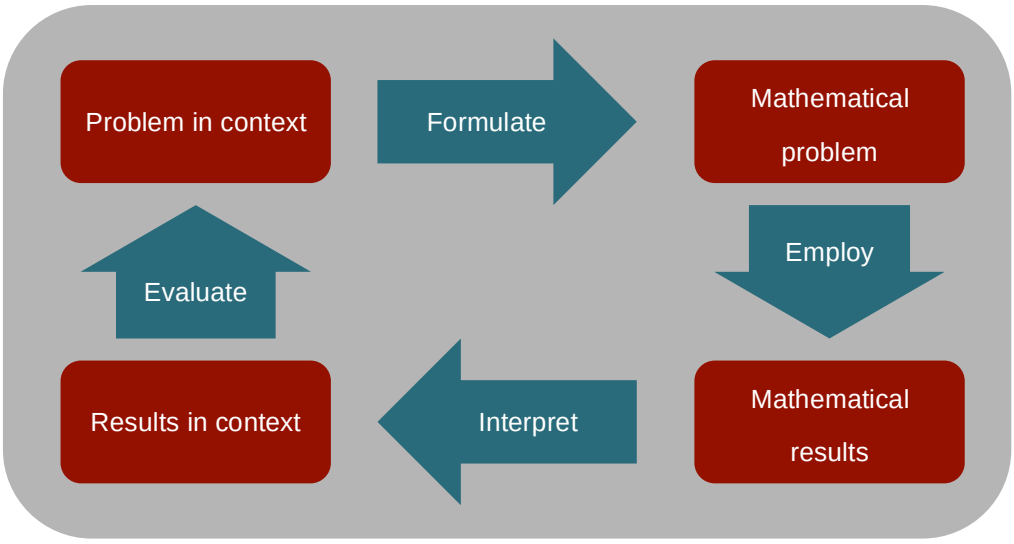
What is problem solving?

Throughout the program I have struggled with the notion of what it means to solve a problem. In all the lessons I observed students were asked to solve a novel problem by applying a concept that they had recently learnt. The problem was used as a means of introducing a new concept. In contrast, I am accustomed to students being unclear as to which concept needs to be used when solving a problem. With 'my' (and of course other peoples') types of problems the focus is on developing students' mathematical processes (practices). Toshiakira Fujji helpfully stated on the final day of the course, the development of processes and concepts are nested together within a problem, but depending on the problem type there will be a different emphasis. Emerging from the course and complementing Toshiakira's explanation (I hope), I will now describe my thinking on some of the differences between the two types of problem:

Firstly, both types conform to Schoenfeld's definition of a problem:

A problem is only a problem (as mathematicians use the word) if you don't know how to go about solving it. A problem that has no 'surprises' in store, and can be solved comfortably by routine or familiar procedures (no matter how difficult!) is an exercise. (Schoenfeld, 1983, p. 41)

When solving a problem students will, to varying degrees, call on different stages in the PISA problem solving cycle (Programme for International Student Assessment 2015) shown below:



1. Formulating the problem: Making sense of the problem situation
2. Employing mathematical concepts
3. Interpreting results for the given situation
4. Evaluating results within the given situation.

The problems I have asked students to solve emphasise Stages 1 in particular, but also 3 and 4. The concepts used in Stage 2 are generally familiar and straightforward for students to implement. However this is not the case with Japanese problems. It is Stage 2 that is emphasised in their problem solving. The other stages, from what I have seen so far, are fairly straightforward. The problematic situations are created to develop a particular concept, whereas 'my' problems are

mainly concerned with developing students' capacity to make sense of a problem, interpret and evaluate results. In so doing the Japanese problems will also develop students' mathematical processes (practices), and mine will also deepen students' understandings of concepts. However, in both cases, these 'stages' are not a priority with regard to student learning.

Furthermore I speculate that many of 'my' type of problems, particularly the modelling types, lend themselves to a wider range of solution strategies. This in turn may mean they need to be planned for in a different way to what I saw in lesson study.

Next steps

From my learning on the program I view lesson study as a means of building a professional learning community in which teachers collectively improve their knowledge of content and pedagogy by focusing on student thinking. And it is this focus that accords with my own interest in, and research into, student thinking when problem solving.

In the midst of teachers' busy schedules, I see lesson study as a desirable antidote. It can provide space for teachers to focus on an issue of importance and study it with colleagues in the place of learning: the classroom. Based on sound research they can collectively develop ideas for a research question that will help improve their own and their students' learning. Moreover, these ideas will not just be talked about at lesson study meetings and in the staffroom, but brought to life in the classroom, observed and analysed. The authentic, shared classroom experiences, together with an ongoing sense of working together to figure out solutions to issues of learning can, I hope, promote a collective sense of efficacy. Without this shared experience, the complexity of student learning in the classroom can be by-passed by teachers, particularly when currently there exists overwhelming demands to 'get results'.

Lesson Study for Problem Solving has been a central research concern for the Centre for Research in Mathematics Education, within the University of Nottingham, for the past two years. The university needs more trained Lesson Study advocates to take this work forward in the future. I hope the experiences of the course allows me to be one of these advocates.

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David Freeman

The time spent looking at problem solving, research lessons and learning more about lesson study in Japan has been a valuable learning experience. It was a unique opportunity to see lesson study first hand and a chance to hear from some knowledgeable people who were open to sharing their expertise with myself and the other delegates.

The visit has strengthened my belief that if an institution is looking at building an effective programme focusing on the development of student's mathematical understanding, then lesson study should play an integral role. It is something that I will be using to drive forward the use of problem solving at all levels with the students and teachers I work with. It will also help improve the teaching of the newly formed Level 3 Core Maths qualification that I am currently developing in schools which has problem solving very much at the centre of the course. My reflection will focus on what I see are the key features and benefits of this approach and what I will take forward in my practice and hopefully develop as a feature of professional development in the schools I work with in my current role.

A lesson study cycle starts with a clear overarching aim that feeds into the lesson influencing the plan and in turn the aim of the lesson. The careful selection of the question is crucial, not only in developing the student's mathematical understanding but the development of the participants teaching and their understanding of how mathematics is learned in their classroom. This extends beyond just the planning team to any teacher observing the lesson and post lesson discussion.

The lessons are meticulously planned including anticipated student responses. These predicted responses will include possible misconceptions, by predicting student responses teachers are encouraged to think deeply about how the students will approach and solve the problem. The way in which the solutions will be presented is also carefully considered. The lesson plan will include a board plan that is designed to highlight and contrast the different solutions to the problem and discuss the merit of each one with the class.

Each of the lessons that were observed had a key problem at its heart which was used to drive the learning. I do not think it should be underestimated the time and thought that goes into selecting each of these problems. They are carefully constructed to include a context to engage and excite the students, build on their prior knowledge and on occasion, merge different strands of mathematics building connections. Each of the lessons started with a single problem that the students were given some independent time to solve. Very often this was the only problem used in the lesson again showing how important it is to choose a rich problem solving task. As the students solve the problem, the teachers carefully moved around the room noting each of the student responses which influenced their choice of students during the discussion phase. In the majority of lessons that were observed, students generally worked independently however, when they did work collaboratively sharing ideas and approaches, they were able to do so clearly and insightfully. When students did struggle they were given hints and on some occasions, opportunity to receive extra guidance from the teacher. This extra guidance was again given through questioning encouraging the students to think through the problem. The productive struggle time was key to the development of the student's problem solving skills, giving them time to think through the problem and have a chance at solving it. The way in which the students present their solutions was another example of the level of thought and detail that is applied to the teaching of mathematics. Students are encouraged to share their ideas so it becomes essential that they write them in a clear and constructed way. This is something that is developed at a young age and is a feature of the text books.

The post lesson discussions play a crucial role in the process. These vary depending on the scale, whether it is a school or district based event but all serve a clear purpose. The feedback during the post lesson discussion is very often not personal, it is about the teaching of the mathematics. If the lesson does not go to plan, it becomes an opportunity for all participants to learn further from the experience. The level of discussion was always generally high with contributors looking deeply at the learning that was taking place. It was always about the learning of mathematics and the way in

which the students solved the problem which made the process more powerful. Another key feature in developing further, is the presence of senior staff and the role they play. At all of the post lesson discussion the Principal of the school and many senior staff were present. Some taking more of leading role in the preceding than others but their presence elevated the importance of the lesson study and would have given them some clear indication to the quality of mathematical teaching that is taking place in their school. The role of the final commentator was another crucial feature of the post lesson discussion. Their comments were very insightful giving all involved food for thought and summarising the process giving an academic view point. A particular closing comment that resonated with me was when a commentator reiterated that the problems and questions we ask should be rooted in the problems that students have learning mathematics and the questions that they ask.

Moving forward, I will be working closely with colleagues looking at how lesson study can be integrated into the teaching of mathematics. Problem solving now plays a major role in the new curriculum and lesson study can play a key role in the development of how best to deliver problem solving centred lessons and facilitate the level of discussion needed to be successful. Lesson study has already been added to the course of study for trainee maths teachers in our schools direct program and public events will be held throughout the upcoming academic year in conjunction with the local Maths Hub. All of these activities will stick closely to the Japanese model with the only slight change being that people observing the lessons during the early events will be given time to discuss the lesson before taking part in the main discussion. Lesson study has been shown to work and I look forward to using it moving forward, not only developing the teaching of others but also my own.

Dean Rowley

As I think about my time in Japan on the Impuls 2016 program, I am sorting my thoughts into three main sections; Japanese Mathematics Teaching and Learning, Japanese Lesson Study and the possible impact on teaching of mathematics in the UK.

There is a clear belief in the Japanese curriculum that mathematics can be taught through problem solving (and not use problem solving as assessments which is seen in many other countries) with the need to put a lot of thought into the problems used. This is seen in their research-defined textbooks that make children think about the problem at hand and more about the method and understanding of the method than the final answer. It is refreshing and powerful to see the discourse happening within the Japanese lessons as students discuss and explain various methods, not always looking for the "best" method but to deepen their understanding of the mathematics. This is also seen within the teaching and the planning behind the questions being asked of the students and the time spent by teachers thinking about the possible solutions produced by students. The power of an example to bring out a misconception is at the heart of good teaching and learning and these lessons have this in abundance. The discussion I saw within the classroom really focused on the mathematics at hand and the ability to not only understand your own method but to think through others and explain their thought processes. Working on others ideas really pushed your mathematical skills to the limit. The need for children to think individually about a problem and grapple with their own understanding before joining group work was at the heart of the experience and really made paired, group and class discussions much more mathematical and active. This was clearly seen within the classrooms through the board work of the teacher. There

was a clearly defined flow on the board to enable all solutions to be seen together and how they linked to each other and the context at hand (This is not always seen within the UK either through the use of smartboards in which each slide disappears as the next appears ro through a lack of thinking about the structure of the board work). Connections are clear and concise and also it enables revision material to be collated in a more effective fashion.

The methodology behind this wonderful teaching and learning is of course lesson study. The best professional development tool I have ever seen in my career that can really analyse student learning and understanding. The Japanese system of lesson study gets teachers planning together on misconceptions and the problem needed to get to the heart of this but then the real power of the observation follows which allows all attributes of the lesson to be looked at; from the board work, individual student learning, teacher presentation, individual problem solving. These are dependent on the goals of the lesson, which are related to the research themes of the school or district depending on the lesson at hand. This then comes together in a clearly defined post lesson discussion where the emphasis is always on student engagement and learning and how these research lessons have improved what has come before or bring up new ideas to work on. This discussion enabled the teacher to reflect on their teaching and then the observers to question their thinking behind decision or suggest improvements based on their observations. This professional discourse was unlike anything I have seen in the UK and really made me feel engaged in teaching and learning again and the need for all teachers, whatever their stage of their career to be constantly thinking about learning and pedagogy rather than just teaching to the test. It was very impressive to see that lesson study is used within all areas of schooling including non academic areas of school lunch, swimming, playtime etc. An example of this being that a prefecture has certain schools working on the best use of ICT in teaching mathematics. This approach ensures that these uses are really researched and developed with students rather than hoping for individual teachers to lead this development on a wide scale. The fruits of this approach then enable the textbook to be reviewed with better problems and examples or at a school level the students to become better mathematicians, alongside the teachers developing their expertise of pedagogy and mathematics also. Yes there are still developments needed in the Japanese system but this is known and why lesson study is so powerful as a tool for development.

The ultimate question is then how this will be taken back and effect the mathematics teaching and learning within the UK. Firstly we do not have research-defined textbooks that use the best problems to prone misconceptions and are reviewed through the use of classrooms. This means that teachers in the UK are always desperately searching for good problems to use or hoping for individual teachers throughout the country to lead the way. Without systematic research within classrooms how do we really find the best problems or methods for dealing with misconceptions and learning. Through the latest changes to the national curriculum and examination framework there is now a big push through the curriculum for all students aged 4 to 16 to undertake problem solving in their mathematics lessons. This has not been thought through and I worry whether this is as an assessment tool rather than teaching through problem solving and evoking discourse about mathematics to deepen understanding. We are trying to separate context and process and the Japanese system has shown that this is not the route to take. The use of lesson study enable teachers to put their professionalism back on top of the agenda, and the need to discuss mathematics, and how children learn best. There is still a need to find a quick fix and teach a trick in the UK and through greater professionalism we can work on process and context together and deepen the understanding of all students. This is a wonderful opportunity to put researching back in teaching and remind them that without research we are not moving our understanding forward. The communal aspect of discussing reasons behind our teaching choices will grow the expertise of all teachers and with a shortage of mathematics teachers in the UK we need to ensure that their professional development is the best that there is.

I read a lot of articles that say that people have had their eyes opened by seeing a new system or

method and always been slightly apathetic towards these reports. However, this research trip to Japan has not only opened my eyes to lesson study but also "blown my mind" to the possibilities that research can have within the classroom and learning and thinking of students. I think that as educators, we must ensure that we use our communal skills as professionals to develop the best pedagogy that enables everyone to deepen their understanding. We are all continual learners and also researchers and must start to use lesson study to grow these attributes. In a climate of so much change and constraints this has enthused me to remember why I entered the teaching profession in the beginning.

Graham Charles

Reflective journal about mathematics teaching and learning in Japan and Japanese Lesson Study

My intention is to look at how we can use Japanese Lesson Study to support professional development for Maths teachers in England. The journal is split into three linked sections:

1) Japanese Lesson Study
2) Problem Solving in Japanese Maths Lessons
3) Practical considerations to use Japanese Lesson Study and Problem Solving approaches in England

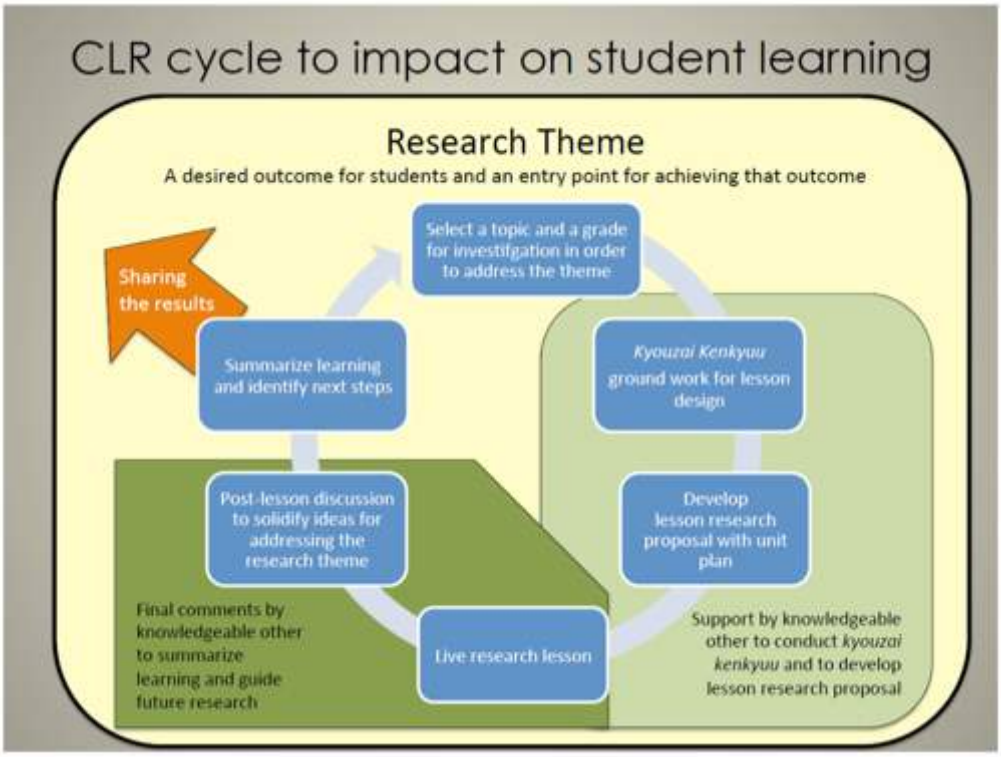
'Mathematics Problem Solving' is the most popular request for professional development support from teachers in our Maths Hub region in England. Lesson Study has been used successfully as a process to accomplish specific teaching-learning goals in Japan, particularly with problem solving approaches, where there is a sense that learning by reading, listening and seeing alone may not be sufficient to develop expertise. Lesson Study was 1 of only 2 (the other being SKE) out of 643 professional learning interventions identified to demonstrate impact on students' mathematical proficiency (Gersten, Taylor, Keys, Rolfhus & Newman‐Gonchar 2014).

The third section highlights practical considerations of non-negotiable key aspects which would help secure the authenticity of Japanese Lesson Study for use in England. Many of these differences may also be relevant for consideration in other countries.

Japanese Lesson Study

The cycle diagram below from Professor Takahashi emphasises the importance of research as an integral part of Lesson Study, starting with a question, not an answer. Collaborative Lesson Research (CLR) has 6 key components:

1) A clear research purpose
2) Kyouzai kenkyuu (in-depth research of lesson theme)
3) A written research proposal, typically formed over 6-8 weeks
4) A live research lesson, with the Koshi ('Knowledgeable Other'), and post-lesson discussion
5) Koshi (bringing knowledge from research and the curriculum)
6) Sharing of results



My initial focus was to clarify similarities and differences between authentic Japanese Lesson Study and experiences of Lesson Study in England. The role of Koshi is crucial in Japan. The Koshi would typically be a professor in education at a Higher Education Institution, with research experience of learning in Mathematics. Lesson plans are submitted at least one week before the lesson, allowing time for the Koshi to dissect plans and bring the research together to be shared in the post-lesson discussion.

In England, teachers tend not to share lesson plans with the observer for routine (non-Lesson Study) observations. When plans are shared, they are usually received at the start of the lesson, sometimes not read, or given limited recognition. Observations, often only 25 minutes, tend to focus on evidence from pupils' books, with some consideration of the actual lesson, sometimes followed up by brief 'debrief/feedback'. A recent shift to allow greater teacher autonomy (rather than a team of teachers) to make a professional judgement about how to teach is not easy for an observer (often non-subject specialists) to fully understand the planning intentions of the teacher or recognise learning over a longer period of time. A Japanese lesson study would typically take 5 to 10 times longer for the Koshi than a lesson observer in England.

Lesson Study in England typically places greater importance on verbal feedback from students during and after the lesson, focusing upon 3 case pupils. In Japan, the focus is on researchers to analyse impact of the lesson, rather than asking students to analyse and articulate their own progress. The Koshi brings much greater gravitas and focus in relation to lesson goals than feedback received from students. The Koshi also has greater flexibility with regard to which and how many pupils they choose to focus on, as desired during the lesson.

The Koshi must control what they see live during the research lesson, so should not watch recordings or viewing by screen, despite the temptation to cut travel time or costs. These 'live eyes' provide flexibility to allow the Koshi to see the big picture, having pored over the lesson plan in detail, as well as their key role of contributing to the post-lesson discussion. It is much harder to get a true feel of the lesson, having observed two IMPULS lessons from outside the classroom. Similarly, being Tad the interpreter's 'shadow' enabled me to get a greater insight of the work of

students, and make stronger links between diagrams and translated commentary.

Koshi Professor Saino's post-lesson discussion elevated peer commentary and reflections to precise, constructive, well prepared feedback, with a 'fresh eye'. His clarity in explaining suggested developments to progression over time and connections from previous learning provided clear direction for the school. Splitting the feedback into lesson, text book and curriculum sections emphasised this focus. Professor Saino's research amazingly revealed that 72÷3 features in all of the text books.

After one of the research lessons, I agonised about whether the Koshi should intervene to 'support' the teacher if they had significant concerns about the lesson plan submitted. Initially, I adopted the 'prevention is better than cure' philosophy, believing that intervention would lead to students not suffering an inferior lesson experience. On further reflection, I began to appreciate the bigger picture about the role and impact of Lesson Study as being much more than professional development for an individual teacher for an individual lesson. If the Koshi had intervened with suggested improvements to the lesson plan before the lesson, this would have masked the brutal honesty needed about the developmental needs for the planning team and the school, particularly with regard to curriculum coherence and text book review.

Having the principal and vice principal present at the research lesson and post-lesson discussion supports the likelihood of follow up as recommended by the Koshi. A growth mind-set towards Lesson Study is evident in Japan, with a belief that all teachers can improve, and not using 'good' or 'bad' labels for teachers.

Many Koshi develop a relationship with particular schools, supporting longer term sustainable development, monitoring the ongoing impact of actions, as opposed to a more disjointed approach of having many different Koshi.

Japanese Lesson Study has three types:

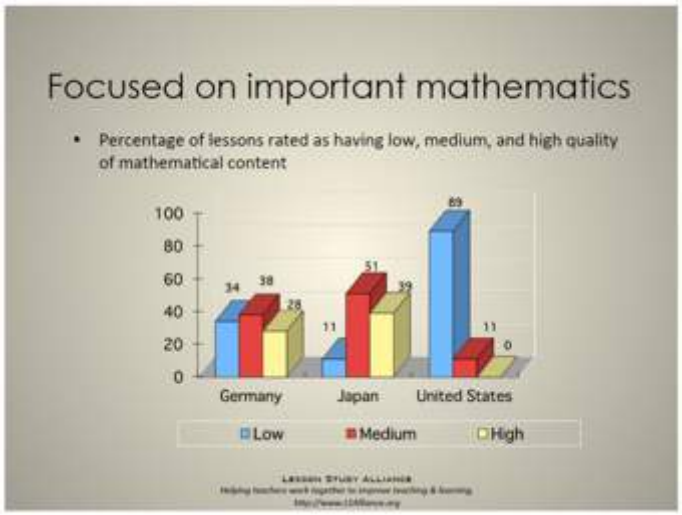
1) School based - theme usually cross subject.
2) District based - shared theme.
3) Cross-district - typically curriculum review theme/mechanism - Possibly 1000+ observers. All Japanese text books are subject to this scrutiny.

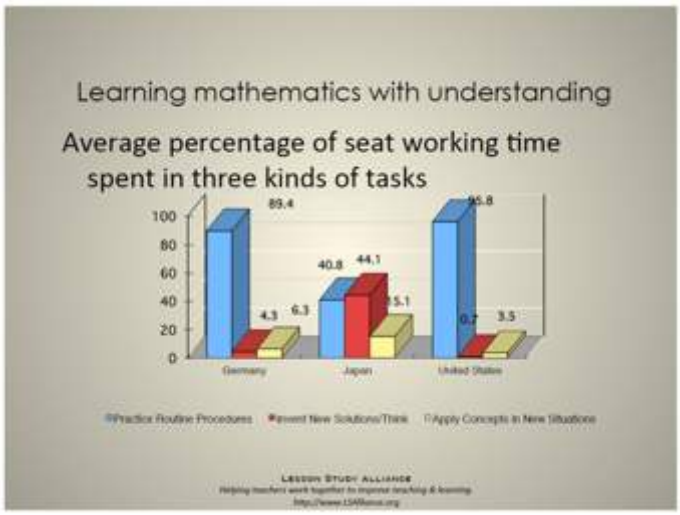
Joint planning is a key aspect of Lesson Study in both England and Japan, which we will retain in our Maths Hub cross-phase work groups. We will continue to use 'Case Teachers' for evaluation of work group impact.

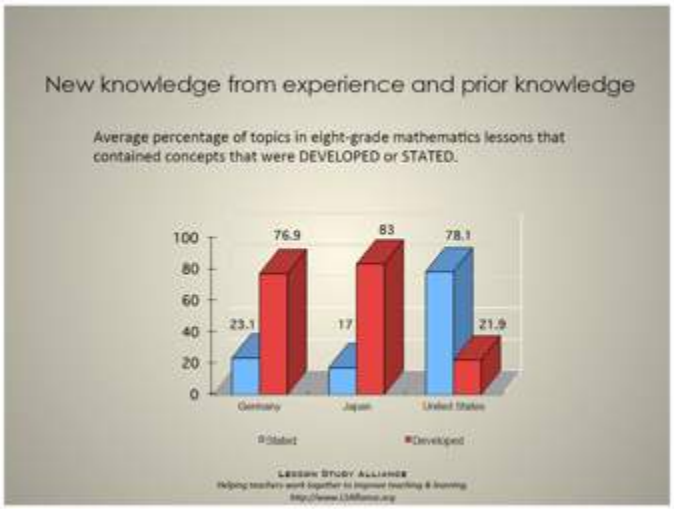
Problem Solving in Japanese Maths Lessons

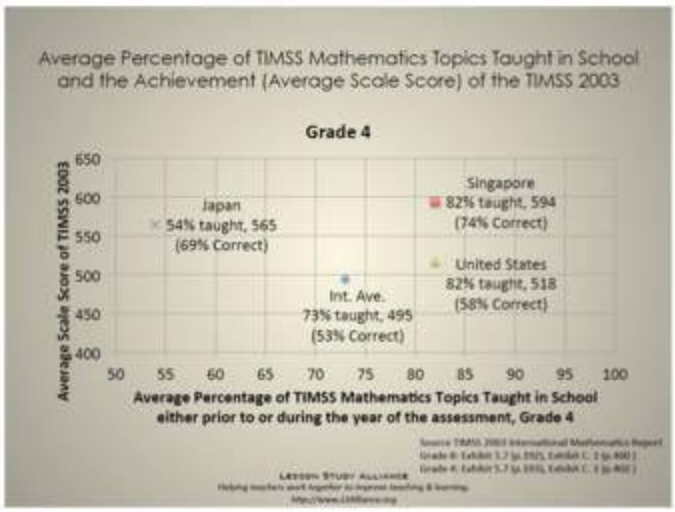
In Japan, it is common for problems to be presented without the teacher having already demonstrated a procedure to solve the problem. The general aim of developing problem solving skills is rated as being more important than to solve a specific task. Teachers plan tasks using text books to prompt discourse which develops reasoning and problem solving. Students are expected to justify solutions and critique a variety of strategies and representations. Teachers plan anticipated responses (alternative solutions and misconceptions). Board work (bansho) should be purposeful to connect different parts of the lesson, and show all solutions simultaneously to be critiqued.

Developing deeply connected mathematical understanding through problem solving, reasoning and discourse is ranked highly in Japan, as shown in the graphs below from the TIMSS video study The Teaching Gap (J. Stigler & J. Hiebert, 1999).









The typical structure to problem solving lessons in Japan is:

1) Hatsumon - Present problem - thinking on own: 5-10 mins
2) Kikan-shido - Problem solving - teacher looks for anticipated solutions: 10-20 mins
3) Neriage - Compare and discuss - critique solutions. Make connections: 10-20 mins
4) Matome - summing up by teacher: 5 mins

Productive beliefs

The relentless refusal by teachers to "help" individual students by giving answers or support was clear, maintaining high expectations for students to develop resilience through the productive struggle. The problem should be the same for the whole class, with different entry points for all pupils to access the challenge.

The neriage sections were much more than 'show and tell'. We were intrigued to see how students made connections, being asked to develop answers introduced by others. 'What does the number represent?' was a common question. Sometimes this started with a diagram or representation; other times from a calculation. The transform approach (Volume lesson) revealed whether students could visualise where the calculation came from.

The text book introduction to Volume showed intelligent practice to distinguish between additive

and multiplicative reasoning (4x4x4 v 5x4x3). The engaging initial question had neither a formula nor mention of 'volume' to support deeper understanding, as well as providing a hook to engage students. The transform approach provides a problem solving bridge linking understanding between volume of cuboids and prisms.

The level of detail that Japanese teachers plan the board work for their lessons was impressive, rehearsing writing the board work of anticipated responses several times. Images and manipulatives are carefully prepared and selected to be appropriately sized to support effective board work when displayed.

Students' notes and supportive diagrams were meticulous. It appears that precision of mathematical vocabulary used is embedded in routine practice for teachers, supporting students to develop their understanding and reasoning.

Students typically have the opportunity to develop their problem solving skills, through

- a productive struggle to develop resilience, persevering with challenging problems, knowing not to rely on the teacher to provide prompts
- talking to other students (pairs or small groups) or reading their work
- having time to write about or develop ideas that they liked from other students or their own work
- predicting alternative solutions that others may use if they have been successful in finding and reasoning with one solution
- considering a wide range of alternative solutions (including misconceptions) through a carefully planned neriage section to check and develop understanding, making connections, identified by the teacher during the lesson
- the teacher may plan to sit students that have taken different approaches next to each other to deliberately expose them to alternative thinking, to support the development of reasoning skills
- the teacher may offer prompts (after students have worked on their own for 5 minutes) to several students at the same time (rather than individually), possibly recapping on prior learning, or encouraging consideration of representations to make sense of the problem

Practical considerations to use Japanese Lesson Study and Problem Solving approaches in England

This section is intended as a reference point for Maths educators that have already seen first-hand and read in depth about Japanese Lesson Study and Maths Problem Solving. These approaches must not be diluted, adapted or compromised in the name of 'cultural differences'. The key aspects identified below should be made explicit in advance to participants in lesson study:

- The Koshi must have a broad educational research experience of learning in Mathematics, in recognition of the importance of kyouzai kenkyuu as an imperative part of lesson study

- The Koshi must be present to observe the full research lesson 'live', followed by the post-lesson discussion

- The research lesson plan must be shared at least 7 days in advance with the Koshi

- The research lesson must be fresh research, and not a showcase lesson or refinement of an

existing lesson plan – a 'perfect lesson plan' is not a key goal

- The planning team must anticipate student responses, and plan neriage progression, including board work

- The Headteacher and curriculum leader must be present for the research lesson observation and post-lesson discussion

- The classroom used should have sufficient board space to display multiple solutions simultaneously to be critiqued by the students

- The research lesson should be made available for professional development of a wider audience – to share results and benefit from 'fresh eyes' in the post-lesson discussion

Professor Fujii describes Lesson Study as being 'like air' to Japanese educators, 'felt everywhere because it is implemented in everyday school activities', so well established and embedded. With Lesson Study seeming to happen naturally in Japan, I am grateful and appreciative of the opportunity provided through IMPULS to attempt to identify key aspects for its authentic form to be used to support professional development for teachers in England.

Paul Rowlandson

End of Week Reflection

What have I learned about problem solving in Japan?

To the Japanese, these lessons aren't about doing sets of 'problem solving questions' but are about 'solving a problem to learn something new'. This probably sounds just like I'm playing with semantics but there is a slight difference. One way to describe it would be that anything that the students face that they haven't learned how to solve in Japan is a problem. For example, simply finding the area of a circle: if students have only previously learned how to find the area of quadrilaterals and triangles and they are then faced with finding the area of a circle, then this *is* a problem. Therefore, new pieces of knowledge are introduced to the students through problem solving. This way, whenever they are faced with something they don't know how to solve (e.g. if they saw one of our UK problem solving questions), they have the skills to think about how to apply what they know to begin solving it.

Here is a run down of bullet points I've noted down about their approach to problem solving:

1. The purpose of a problem-solving lesson is not to solve the problem; the purpose of the lesson is to *think* about ways to solve the problem and deduce something new from the process. Therefore, most learning objectives say something like *"For students to be able to think about how to..."*

2. The general sequence of lessons tends to be that they have one lesson where they solve a problem

and the next lesson where they do some routine practice to consolidate what they learned in the previous lesson.

3. Problem solving lessons always seem to begin by looking at recapping somethings that they already know that relate to the problem they are about to pose. Maybe one or two questions.

4. For the rest of the lesson, the class will answer only **one** problem and think about it together for around 40 minutes.

5. The lesson will examine many different ways to solve that problem, discuss how the methods are similar and different to each other and also talk about whether certain methods can always work.

6. Students are asked to record their ideas using a combination of diagrams, words and calculations. They also look at multiple types of diagrams. Students are also meant to record their ideas in a way that their friends could read and understand.

7. In the lesson plan, the teacher highlight all the possible ways that they anticipate the students trying to solve the problem and maybe which ones they would like to highlight during the discussion.

8. It seems to be the way that the teacher will pose the question and ask students to spend 5-10 minutes working independently on it. During this time the teacher walks around observing what the students are doing but not necessarily helping (maybe very minor hints from time to time). The teacher is mostly looking to see what methods students are trying out so they can plan out the discussion part of the lesson.

9. The rest of the lesson is very much dominated by interactive/dialogic discourse between students and the teacher as the teacher purposefully selects students' ideas to share in the order he/she want to discuss.

10. The teacher and students are very patient during the whole class discussions. The teacher completely resists the urges that I know I often get to wrap things up with a teacher explanation and move on. Instead they will keep bouncing things around until they feel that everyone has had enough time to fully understand the point of the lesson. In one lesson we went around 30 minutes without hearing the answer to the question '48 divided by 3'.

11. The teacher asks for multiple students to explain the same method and for students to re-explain things that have already been explained by others.

12. For one method the teacher may first ask for a worded explanation, then ask for others to describe that same method with a diagram and then draw out the calculations. But then for the next method they may first ask students what calculations they wrote and then ask the rest of the class "Can you describe what this student has done? When have they got these numbers and operations from?", then follow up with the diagram and explanation.

13. They always have a summary/reflection of what they have learned from the process. This is often then followed by looking at one or two more problems very quickly. They don't necessarily always solve them, but they discuss which of the methods covered they would apply to the problem.

14. Teachers plan their board work. Whereas UK teachers often write a little bit and then rub it out before writing another bit, very little is rubbed off the Japanese teachers' boards. This is so

that the students and the teacher can regularly refer back to previous parts of the lesson and make links between different methods. By the end of the lesson, the class can see the full learning journey from the very start of the lesson to the end.

What have I learned about lesson study in Japan?

My school and I are very much at the very start of our journey using lesson study. We had very little understanding of how it works and what it was for before I went on the trip. However the pre-trip reading provided by Akihiko Takashi was extremely useful and gave me a very good insight into what to expect. So much so, I had prepared a Power Point presentation for my colleagues on 'What I Have Learned About Lesson Study So Far'.

Below, I have listed some of the additional pieces of information that I have learned about lesson study while I have been on the trip. Some points are about logistics, mechanics and what lesson study looks like in practice; other points are about an increased appreciation or understanding of the purpose and impact of various aspects of lesson study.

The **research lesson plan** proposals have typically been around 10 pages long and have included all the things listed in my original Power Point. The explanation of where this lesson fits within the unit of work is actually quite detailed, including outline of what students will learn in each lesson for roughly 10 lessons (the research lessons have mostly been one of the middle lessons in the series) and how each one will build on the previous one. They also set out all the different responses that they anticipate from students for the main problem, highlights the key ones that the teacher will aim to focus on and a drawing of how they want their chalkboard to look any the end of the lesson.

During the lesson, there have typically been around 10-15 teachers in the room watching the lesson, including the principal for the elementary schools. They seem to divide their efforts in different ways: one may write down a transcript of what the teacher says, one writes what the student says, some will take photographs of the board and some take photos of students' work. Some may stand near the same group of students throughout the lesson to watch how they construct their ideas from the start to the finish and some circulated the room to compare students' approaches to the work. There were no hard and fast rules to what they did and each school organised themselves differently.

However the things that all schools had in common was that the observers did not interfere with the lesson in any way. They didn't help the students when they got stuck and they didn't talk to the students about the lesson or what they were doing. When the students were working independently, observers would walk between the desks to see what the students were doing and saying, but when there was a whole class discussion the observers would stand around the edges of the room. It was almost like they were silent ghosts who could be seen but weren't entirely present.

The post-lesson discussions lasted roundly an hour and a half. There was usually a panel made up of the teacher (sometimes accompanied by the planning group), a chairperson, the principal for elementary or the head of maths for high school, the equivalent of AP for T&L and a "knowledgeable other". The rest of the teachers would sit around the room (usually in a horseshoe), making notes and providing input.

One of the discussions we observed was dreadful because the chairperson practically fell asleep and left it as a 90min free for all before passing on to the knowledgeable other. However the best

discussion were the ones that were well chaired and often broke the session down into the following parts:

1. A welcome note by the chair
2. A five minute speech by the someone from the planning group about the lesson about the rationale lesson.
3. A five minute speech by teacher who delivered the lesson reflecting on whether or not it went to plan.
4. An open discussion for roughly one hour about the lesson. The observers would either make comments based on what they saw or ask questions to the planning group. Sometimes member of the panel may ask questions too. In the most productive sessions the discussion was broken up into different sections (e.g. 10 minutes talking about students working independently, 10 talking about the whole class discussion etc).
5. The chair would interject at different times to summaries the key points that had been discussed so far before taking further comments or questions. They would also do a slightly more comprehensive summary at the end of the discussion (around 3 minutes long).
6. The knowledgeable other would do a 15-20 minute presentation.
7. The chair or principal would wrap things up, summaries what they think the school should take away from the process and thank everyone (3-5 min).

Someone usually takes notes or minutes of the discussion too. Also in some cases, the observers had written post-it notes of key points about the lesson before the session and stuck them up on the wall.

The knowledgeable other was often referred to as the 'final commentator' and was always someone external. Their role was to bring fresh insight into the school so that the same ideas were just being recycled periodically between internal staff and ultimately to raise the discussion to a higher level. For each research lesson they would receive a copy of the research lesson plan proposal a week in advance so that they could consider it carefully, look up things that relate to it and prepare the bulk of their Power a point presentation in advance. They would then observe the lesson and make additions to their Power Point during the post-lesson discussion (usually to insert photos from the lesson, things they observed or points brought up in the post-lesson discussion).

I'll be honest and say that before I went I didn't quite understand the value of the final commentator and thought it would be an extra hassle to arrange for people from outside to come to school for this purpose. But each day I saw how important and powerful this role was.

After the research lesson, it apparently tradition for the whole school or department to go out for dinner together afterwards. It is also customary for the teacher who delivered the research lesson to have his/her meal paid for by the rest of the attendees. Nice touch.

Rachael Horsman

The Japanese Curriculum; Through observation during the IMPULS 2016
The Japanese curriculum, we witnessed, has been fine-tuned and honed to provide students with the chance to learn in such a way that no 'quick fixes' or 'major tricks' are needed. Understanding is cleverly developed through the flow of the learning and at each stage new learning is carefully

elicited rather than delivered. This is enhanced by teaching through problem solving. The development of the curriculum is a considered and thoughtful process with input from educational experts and teachers themselves. Careful trialling and a slow run in ensure that the content and delivery is researched, considered and prepared for.

Q. What research has been carried out to develop the content and order of the Japanese curriculum? Will it influence the work of Cambridge Maths?
Q. Who is the best person to discuss this with in Japan?

Japanese Teacher Training; Through observation during the IMPULS 2016
Japanese teachers are highly professional. They are dedicated to their own learning as much as that of their pupils'. They actively participate in professional development and see it as an essential part of their career. Teachers research various pedagogies, resources and the curriculum itself, and take part in high level discussions about learning. Japanese teachers welcome constructive feedback and ask others to inform them how they can improve, at times with very specific questions. They work in an environment where observations are used as a formative not summative tool.

Q. Do Japanese teacher receive feedback on their teaching from their pupils in any way?
Q. How, if at all, are Japanese teachers monitored or assessed?
Q. Is there a Japanese equivalent to performance management?

Japanese Problem Solving

Japanese problem solving approach to teaching, *Mondaikaiketsu no jugyou*, uses a different set of didactic techniques to other industrialised countries (Hiebert, Stigler and Manaster, 1999). Developed over years the approach emphasises "pupils' attitudes toward and ability to communicate mathematics, rather than mathematical skills" (Asami-Johansson, Y. , 2011, p. 1).

The problem solving approach is supported by inspirational resources developed by practicing teachers that include teaching ideas, lesson plans, and well constructed problems that are linked by the proposed teaching methods. (Souma, 1995, Kunimune and Koseki, 1999, Tsubota, 2007 in Asami-Johansson, Y. , 2011)
Some important characteristics and influences of Japanese problem solving are identified by Asami-Johnansson, 2007. These include; the influence of Dewey's theory of reflective thinking (1933) and Polya's insistence on the importance of guessing (1957). Japanese problem solving has a focus on the first encounter and subsequent exploration of a problem engaging pupils. This alongside carefully and precisely defined mathematical content set Japanese problem solving apart from what others to consider to be problem solving. Souma (1987, in Asami-Johansson, Y., 2011) describes tasks as "open - closed tasks". Open in the fact that they stimulate thought and conjecture, pupil exploration, some guessing, and multiple methods of solution. Closed in the fact that they result in discussions and work on a well-defined area of study that is predictable.
This means that what may be considered a routine problem to some students can be transformed into a problem solving task by small modifications and presenting it during a carefully constructed sequence of learning. This can lead to *"conjectures, new problems and methods that productively connects the local mathematical organisation covered to more global ones* (Asami-Johnansson, 2007).

Through observation during the IMPULS 2016

During the IMPULS project I was able to identify several stages within a Japanese problem solving lesson that match those described in research papers (Hiebert, Stigler and Manaster, 1999, Asami-Johnansson, 2007, Archer. R, 2016);

1. **Posing of the problem, *hatsumon***

During this stage the teacher poses the problem for the lesson. They clearly explain the task and expected outcome to the class.

2. Independent problem solving, *kikan-shido*

During this time pupils work independently on solving the problem. Pupils grapple with the problem on their own with very little or no discussion. They are challenged and have to persist, some do not succeed, others find multiple solutions. They may refer back to previous lessons in their notebooks. The teacher will identify the variety of solutions being constructed by pupils. They may call together a group who are struggling and offer some additional support. Finding the answer is not the aim, but finding routes to the answer and the careful explanation of those routes is key.

3. Whole class discussion, *neriage*

The teacher leads a whole class discussion. They will carefully and precisely work through several of the solutions in the class, producing exact and detailed notes on the board that are often copied into pupils' notebooks. Solutions and explanation are elicited from a number of members of the class through highly skilled questioning and clarifying of ideas.

4. Summary and Reflection, *matome*

Toward the end of the lesson the teacher will often ask pupils to summarise what has been covered and how the new learning or understanding built upon previous work. Every pupil will then write a reflection of the lesson in their book. These statements evaluate the pupils' understanding, explain what and how new knowledge has been developed and may contain questions for future work.

It is clear from observation that the problem solving approach is enabled by the design of the curriculum and text books. There are carefully designed, researched and developed with the aid of teachers and education experts in such a way that year on year small increments in learning can be delivered through problem solving. This style of teaching enables a significant amount of mathematical reasoning to take place, for thinking to be emphasised rather than just skills and for different sections of a lesson to be linked. Furthermore pupils are creative in inventing new procedures and analysing new situations. Yet, because of the carefully constructed problems, teachers are able to subtly control the specific learning that goes on. (Hiebert, J, Manaster, A. B, and Stigler, J. W, 1999)

Other observations

Student Notebooks

Pupils have complete ownership of their notebooks. They keep detailed tidy notes that describe their learning. Both through speaking to teachers and observation it is clear that pupils are taught at an early age what to write in their notebooks and how to ensure that they are usable learning documents. Pupils refer back to previous lessons, read previous examples, workings and reflections in order to solve new problems. They may even reference the date of knowledge used to solve a new problem. The purpose of their recording is not just to communicate to a teacher what they have understood but to give a record and explanation of their own learning journey. Notebooks are a tool used to solve practice questions, prepare for assessments and help in future learning.

From observation there is no incorrect work in notebooks. This isn't forbidden in anyway, in fact at least one text book specifies that incorrect workings should be left in notebooks and annotated. It does however seem to be a response to the importance given to clear and detailed notes being kept and possibly a cultural influence.

Notebooks aren't marked in a huge amount of detail. Teachers mark pupils' reflections and will comment back about the quality of the reflection or pose a next steps statement.

Q. How do teachers assess pupils' personal understanding if everything is correct in a notebook having been (possibly) copied from the board?

I have a theory that the reflections written at the end of each lesson are key here. I am beginning to feel that pupils are well trained in analysing their own learning, can construct a truthful and

honest reflection on their learning, and will absolutely give true feedback to their teacher. Teachers are skilled at analysing reflections. They recognise a generic statement that indicates a shallow or no understanding and can identify pupils who have not fully grasped or formed their own understanding of new content.
Q. What happens if a pupil doesn't understand? Or cannot apply the new learning?
Q. How is this identified?
Q. Who goes to whom to fix a problem like this? Does the child ask for help outside school from a teacher? Does the teacher fix exam time to spend with the child?
Q. How common place is tutoring outside of school?

Text books

Japanese text books and associated teacher guides are a work of art. They are designed and developed by educational experts with input from teachers over many years. They are invaluable to teachers in Japan. These high quality resources ensure that teaching happens in a sequential way, highlight key misconceptions and cover the content entirely. They reflect the ideology of learning through problem solving and model the variety of likely solutions for each problem, but also contain practice questions where new concepts developed through problem solving are put into use (sometimes drawing several ideas together).
With just six publishers all certified by MEXT common threads can be identified. Where text books agree on a specific teaching task, pedagogy or ordering it is because significant classroom research shows that it is the best way to deliver that content. Where texts books differ it is because current research is yet to reach a unanimous decision.

Q. How can this inform text book design at Cambridge University Press?
Q. If Cambridge Maths release text books what can we learn and how from the Japanese authors and publishers?

Board work

Board work is carefully planned, detailed, and presents a clear story of the lesson. Some teacher guides include board plans, and often this will form the major planning part of a typical lesson. There is an importance of colour and established routines e.g. boxing a problem in blue at beginning and reflection in red at the end, the use of magnets to identify contributors and pre prepared sheets to post up. Teachers rarely write anything on board that is incorrect (only seen in one lesson), but instead elicit and write up several perfect solutions to the same problem. Having such high standards allows the same to be expected of pupils. Teachers model everything in the way they behave, address pupils and write their mathematical work.

Questioning in the classroom

Japanese teachers are incredibly skilled at questioning a variety of pupils, of getting a wordy explanation with no calculations from one, getting calculations to match the explanation from a second and going on to a third to link the calculations to the original wordy explanation. This may also happen in other orders for example starting with a list of calculations. They pick up on important parts of calculations, such as where a particularly value came from and are not bogged down in asking pupils to restate formulae e.g. such as the area of a circle. Pupils' responses and their own questions are highly valued and a number of schools are researching how to ensure that pupils are listened to in their lessons.
The clarity of language and explanation is extremely high. Teachers don't lead but instead ask for clarification, and multiple explanations. Little if any time is spent off topic or revising previous content, answers are clearly identified with the relevant units and no formulae seem to be written on the board (just applied).
Pupils are not afraid to question their teacher and peers, they also have the confidence to state that

they are lost and need some guidance. When stating they are lost pupils often refer to the teacher for help and ask them to summarise not re-explain a situation. The teachers' opinions are valued but they are not expected to spoon feed pupils. Pupils expect to be challenged and have to work hard.

Q. How has this ability to use questioning so effectively been developed? Has it come from the text books? Is it taught, observed, learnt through experience? Are there resources that support this skill?
Q. Is questioning covered explicitly in teacher training? Or in professional development?

Japanese Lesson Study, *jugyou kenkyuu*

Lesson study has been part of the Japanese education system since the late 1800s and the launch of universal public education in Japan (Makinae, 2010). It has been and is a "fundamental driver of improvement in teaching and curriculum" (Takahashi, A, 2014, p.4) and for Japanese educators "it is like air, felt everywhere because it is implemented in everyday school activities" (Fujii, 2014, p.66). International interest in the Japanese lesson study process really stems from the TIMSS Video Study (Stigler, Gonzales, Kawanaka, Knoll and Serrano, 1999) and the work that followed lead by Stigler and Hiebert (1999).
Currently many models of lesson study exist around the world, although few authentically replicate the Japanese process. Misconceptions and misrepresentations exist, resulting in varied levels of success (Takahashi and Mc Dougal, 2016, Fujii, 2014). Some adaptations have been taken knowingly to support cultural and other specific needs (Archer, R et al, 2013). Even within Japan itself some variations exist and education experts are working closely with schools in Japan and further afield to identify the crucial features that maximise the positive effects that lesson study has on teachers, pupils, text books and the curriculum.
At its heart lesson study is a collaborative, research and experimental approach to teacher professional development (Archer et al. 2013). The process can take place at different levels; school level, district or regional level and national level (Takahashi, 2006). At all levels true Japanese lesson study has key characteristics that can be identified in literature and through my observations during IMPULS 2016.

Environment and Organisation

The environment of learning, a willingness to try, participate, and be critiqued is clear in Japanese schools. Lesson study isn't a summative process, but informs every person involved. This environment hasn't been developed quickly but built overtime and embedded with the school culture. It allows for feedback and lesson analysis to concentrate on the teaching not the teacher. It creates a situation where teachers can challenge each other's beliefs, discuss areas for development and take risks, yet in an atmosphere where things are not seen as personal attacks but areas to investigate, trial and discuss collaboratively.

A Theme and Steering Committee

A school theme is identified at the beginning of a lesson study cycle. Themes will often run over a period of years and inform lesson research themes. Themes may include translating a part of the curriculum into practice, developing pupils' ability to be independent thinkers, or developing pupils written communication skills. A steering group will be convened and ensure that lesson study works towards the school theme.
Through observation during IMPULS 2016 lesson study that was closely tied into the school theme received more 'buy in' from staff. Senior leaders were more engaged, supported suggested improvements, and looked for ways to tackle issues that became apparent during the process (organisational, resource based or training wise). This gives the lesson study process even more influence and importance; a single lesson study benefits the whole school and every member of staff

sees the relevance to their day to day job.

Research and planning, *kyouzai kenkyuu*

Kyouzai kenkyuu is the name given to the detailed research that is carried out by the planning team. For a successful lesson study this will included studying;

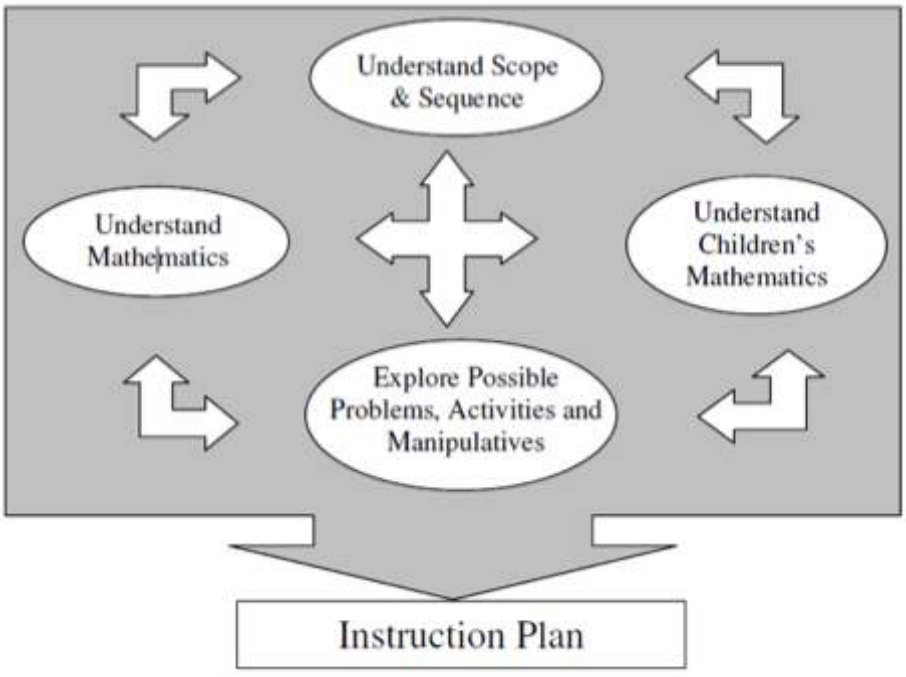
- the curriculum
- available text books (multiple) or instruction materials
- pre and post learning, content and pedagogy implemented, on previous years and future learning
- other background reading

The planning group intensively studies instruction materials (Watanabe, Takahashi and Yoshida, 2008). They consider what the actual mathematical content (knowledge and procedure) is, what it means and why it is relevant. They will discuss the point of a particular problem solving question. How does it meet the learning goal? Why is it presented in the way it appears in a variety of texts? What happens immediately before and after this lesson?

The group will compare ordering of topics within the text books and refer back to the curriculum. They will consider how a current problem relates to previous topics, what should be emphasised, and what form instructional resources should take. Teachers *unwrap the true intent of the textbook authors* (Watanabe, Takahashi and Yoshida, 2008, p. 135).

Part of the research will be to decide if existing materials suite the class and learning in the research lesson. Lesson study offers the opportunity for planning groups to adapt or design a problem or an approach and to reflect on how this meets the learning needs of their pupils.

Kyouzai kenkyuu can be summarised as below;



Watanabe, Takahashi and Yoshida (2008, p.140)

Central to the planning groups thoughts are what will the lesson tell them in relation to their theme and how to teach maths more efficiently.

One product of *Kyouzai kenkyuu* is the detailed lesson plan for the research lesson. This will include the research carried out (possibly also pupil surveys), an explanation of how the lesson fits in to the learning of pupils, a narrative of the lesson, the expected solutions, and a board plan.

Q. What guidance exists for *kyouzai kenkyuu*?
Q. Is there guidance that we can offer school for their *kyouzai kenkyuu*? Or can we model *kyouzai kenkyuu* to the Japanese level?

Research Lesson, *kenkyu jugyou*

The research lesson is enabled by senior leaders at the school. Every member of staff will watch the lesson. Other pupils will either be sent home early or work independently in their classrooms. Observers may include support staff, senior managers, visiting staff, district representatives and the *koshi* (see below).
The observers go amongst the pupils, at particular moments, to get a closer look at their work. They may photo books but may not talk to pupils or offer any help in any way. It is believed that this would disrupt the research aspect of the lesson. Many take detailed notes on their copy of the lesson plan. One member of staff will be scribing the whole lesson and several may be videoing proceedings.
Japanese pupils seem accustomed to having a large number of people observing their class and pay little if any attention to the observers.
From discussions during IMPULS 2016 teachers do not identify specific pupils to observe but gain an overall picture of the classes work and how it relates to the theme being researched. The emphasis is on looking at the learning taking place, how this is enabled or restricted and how closely proceedings follow the expected route.

Post lesson discussion, *kenkyuukyougikai*

Each post lesson discussion follows a very similar path. A compere ensures that things run smoothly and to time, they ensure each member of the audience may participate and that key points are highlighted.
The typical program is;

- welcome by the compere, thanks and introductions to those present
- initial response to the lesson from the teacher delivering the lesson and the planning team
- questions and discussion from and between the audience to the planning team
- final points from the *koshi* (see below)

During the initial response, by the delivering teacher and planning team, emphasis is given to how the lesson met the research theme, what went to plan and what didn't and any areas that the team would like reflections. Teachers are open to discussion and keen to gain valuable feedback to improve their teaching and understanding of how pupils learn. They may also refer to the *koshi* with specific questions concerning their school theme, research or the research lesson itself.
Discussion between the school staff, delivering teacher and planning team is hugely reflective. Staff feedback their observations including information about the content of the lesson, the class as a whole and on individuals. The discussion goes beyond a simple report of what was seen but all staff reflect on the lesson in depth, how pupils were learning, how closely they reproduced the expected solutions and how the lesson related to the research theme. Many express their thanks and specify what learning they have gained from the observation and lesson plan. Often senior leaders will identify points for future research and direct specific questions to the *koshi*.
Finally the *koshi* offers their final comments.

Knowledgeable Other, *koshi*

The *koshi* is central to the success of lesson study (Takahashi, A, 2014). They don't just wrap up and summarise but offer an in depth analysis of the lesson, the planning, the curriculum and pupil learning. The *koshi* explains the thinking behind the curriculum's development of the topic and text books treatment of the topic, not only in the year of study but also in the previous and next years. They identify the key knowledge being extended in the lesson and may offer suggestions or

adaptations to the presented problems. They can not only provide a different perspective from their own research but also that of other lesson study groups (Fernandez, Yoshida, Chokshi & Cannon, 2001)

Importantly the *koshi* doesn't criticise the teacher but offers evidenced reflections on the *kyouzai kenkyuu*, lesson plan, questions, etc. A poor lesson is, to a certain extent, blamed on a lack of preparation not lack of teaching skills. This ability to reflect on a research lesson demonstrates to teachers how they should be thinking.

The position of *koshi* is hugely important, highly respected and requires a large amount of input. The choice of *koshi* has to be carefully considered. A senior teacher just giving lesson feedback on what is observed is not enough. Japanese knowledgeable others are often education professors or senior teachers (with district level involvement) with significant classroom and research experience. They have a deep understanding of the architecture of mathematics, the curriculum and pedagogy. *Koshi* join together the theory and practice of teaching mathematics.

Q. Do Japanese knowledgeable others receive training in this role?

Most research points to other than their own experience of lesson study *koshi* receive no formal training or guidance. There is a move now in Japan to develop some form of guidance and /or support but as of yet none exists.

Q. Is there some guidance and/or support that Cambridge Maths or Cambridge International Exams could produce (or exists already) for knowledgeable others and lesson study groups?

Outside Japan there are not enough opportunities for *koshi* to learn through experience (Takahashi, 2014). Hence a clear understanding of their role and the reflections given is needed alongside some suggested support and/or training would be hugely beneficial.

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4 External Evaluation of the Program

Programme Evaluation Report
IMPULS Lesson Study Immersion Programme
20 to 27 June 2016, Tokyo

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Executive Summary

1. The IMPULS programme brought an excellent experience to the participants and the learning of each participant was rich and transformative in several ways as evidenced in their reflective reports. The programme was so well organized with a range of activities that included expert-led seminars and authentic immersion in various kinds of Lesson Study – school-based, district-based from lower grades to secondary grades and for different topics in Math. The only concern raised was that it was too intensive. Two lessons within a day gave insufficient time for further discussions about curriculum materials and subject matter related to the topic of lessons observed as well as time to interact with the research lesson teachers to understand more deeply the planning behind each lesson.

2. The participants were able to clarify their own understanding of Japanese approach to Lesson Study such as re-teaching of research lessons and interviews with case pupils as well as their own understanding of Teaching Math through Problem Solving. The participants saw how critical it is to select the appropriate Math problem; the careful planning of lessons with students' misconceptions in mind and consideration of students' entry points; the role of independent work and peer discussion; the questioning skills of Japanese teachers in the 'neriage' phase of the lesson; and the focus on the exploration of different solutions to the problem rather than finding out the right answers to the Math problems.

3. There are two aspects of Japanese Lesson Study the participants found missing or inadequate in their own practice of Lesson Study in their respective countries – Kyozai Kenkyu and the role of the "knowledgeable other". They were impressed with the detailed research lesson plans that reflected the amount of study and research Japanese teachers engaged in prior to teaching the research lesson. They saw in the lesson plans how Japanese teachers anticipated students' responses to various tasks in their lessons as well as plan their blackboard work. While they observed varying skills among the knowledgeable others during the programme, they were convinced of the important role of the knowledgeable others in lifting the quality of the discussion of the research lessons.

4. The IMPULS programme also provided participants with many glimpses into the culture

of Japanese schools and classrooms. What they saw of the classrooms ran counter to what they had earlier assumed – that Japanese students are quiet and passive and Japanese teachers are strict and serious. Instead they saw the close relationships that teachers have with their students and the thoughtful banter among students and between students with teachers. The participants were impressed with how carefully the students wrote their journals during and after the lessons.

5. The participants began the IMPULS programme with high expectations of their learning on many dimensions related to Japanese Lesson Study and Math problem solving approach. They met and even exceeded these expectations on some aspects that were more visible in the IMPULS programme. These included the development of Math units and lesson plans as they were given several detailed Math units and lesson plans to examine; how to organize a successful post-lesson discussion and how to provide comments as a knowledgeable other as they observed seven post-lesson discussions in total; how lesson study is conducted in another country and in different contexts as they had the authentic experience of observing Japanese Lesson Study in action and in different contexts; cultural approaches on Mathematics teaching and learning and Japanese approaches to teaching Math as they observed several Japanese Math problem solving lessons and had discussions with Japanese math experts. They were also able to observe a typical Japanese school day through their walkabouts in some of the schools they visited and so gained some knowledge of Japanese school system.

6. The aspects where the participants' expectations were not fully met could be done by having more discussions within the IMPULS programme, e.g. analyzing and interpreting students' verbal comments; analyzing students' work; differentiating and offering support for struggling learners and strategies for working effectively in a group. While the feedback was useful, it was not possible to cover all the aspects that they expected to learn in the 10-day programme.

7. The impact of IMPULS programme goes beyond the powerful learning within the programme. The participants believed they were inspired to change the ways they would implement Lesson Study in their respective countries upon their return. To sum up the words of one participant, "this is a marvellous program and it should be continued".

"Lesson Study, though it now feels like the air, did not appear from nowhere in Japan; it was thoughtfully built from the ground up"

"Unless lesson study has been engrained within the culture of a school, it is also unlikely teachers will want to dedicate their limited time to it"

Source: Participants' Reflections

Introduction: Looking through the window and at the mirror in the IMPULS programme

The IMPULS Lesson Study Immersion 2016 Programme is "designed to give mathematics education researchers and practitioners outside Japan an opportunity to examine authentic Japanese Lesson Study in mathematics classrooms". Hosted by Tokyo Gakugei University and funded by Japanese Ministry of Education, the major purpose of the programme is to "receive feedback on the strength and weaknesses of Japanese Lesson Study and to discuss how to improve math teacher professional development".

International participants who spent a week observing lesson study in action in several schools provided an external lens exploring and examining Japanese Lesson Study which is deeply embedded in the culture of schools in Japan. This immersion in authentic settings allowed them to look through the window and in the process look at the mirror to reflect on their own understanding of what are the essential features of Japanese Lesson Study and examine critically their current Lesson Study practice in their respective countries.

Their perspectives about Japanese Lesson Study surfaced and deepened through dialogue with Japanese Mathematics Lesson Study experts, Professors Toshiakira Fujii from Tokyo Gakugei University, Akihiko Takahashi from Tokyo Gakugei University/DePaul University and Ted Watanabe from Kennesaw State University during expert-led seminars and with each other. There were also discussions and briefings conducted before and after observations of research lessons. Informal talk at other times among the participants over meals and other social events was also a significant source of learning and reflection. The participants reflected on how different and similar Lesson Study and the teaching and learning of mathematics were done in their own countries and considered what could be applied and what could not be applied to their own contexts.

This evaluation report is based on multiple sources of data - the participants' daily and final reflections, the surveys administered before and after the programme, the group lesson reports and serves to examine the usefulness and impact of the IMPULS programme on participants. A key question is whether participants deepened their understanding of Japanese Lesson Study and how Japanese teachers teach mathematics the problem solving way. Were they inspired to take their learning back to their home countries and make a commitment to change how they have been doing Lesson Study?

Diversity and Lesson Study Experience of Participants

The IMPULS 2016 programme attracted a total of 33 participants from the following countries: Australia (3), Malaysia (1), Netherlands (2), Portugal (2), Singapore (1), Switzerland (1), US (12), UK (11). Eight of the participants were from teacher education departments in universities/higher education institutes in Australia, Malaysia, Netherlands, Singapore, Switzerland and the UK. The majority of participants from the UK cluster were independent consultants/math coaches and school heads. The participants from the US cluster of schools were mainly school teachers. There were also 1 school teacher from Australia and 2 from Portugal. This diversity of participants who are researchers, teacher educators and teachers provided fertile ground for rich discussions with differing perspectives.

Prior Experience with Lesson Study - Figure 1 below revealed that 16 participants had been involved in Lesson Study for 3 years and more. Four participants had no experience with Lesson Study. Two of them were teachers (ID 7 & 21) and two were school leaders (ID 30 & 32) but all planned to be involved in lesson study the following year. An important question to think about is the basis of selection into the IMPULS programme and whether participants with some experience in Lesson Study would benefit more from the progrmame.

29 participants experienced Lesson Study in mathematic classrooms. 7 of them have experienced lesson study in classrooms beyond the subject of mathematics. The diverse mix of participants involved in Lesson Study in their respective countries in various ways enhances the learning of everyone within the programme. A large number of participants appreciated this very much.

"the chance to have informal discussions with a variety of teachers from across the world all of whom brought different experiences and views to the table. This was most helpful" (ID25).

*"Participating in many research lessons and discussions in open and committed schools, with teachers and educators from all over the world, helped by wonderful graduate students and guided by so knowledgeable sensei was, of course, a privilege" (*ID10).

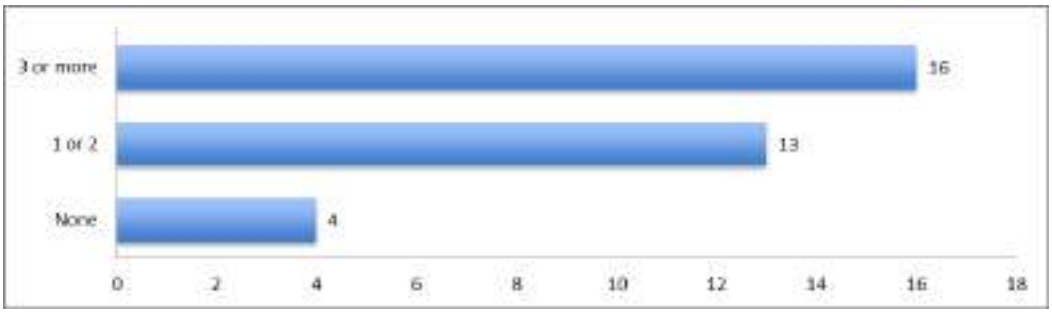


Figure 1: Years of Involvement in Lesson Study

Those with Lesson Study experience was exposed to it in their home countries except for 2 participants who had exposure not just in their home countries but also in other countries. So for many of the participants, the IMPULS programme provided their first experience of observing Lesson Study activities outside of their home countries. Most of the participants (16 of them) have experienced at least 4 cycles of lesson study (see Fig 2 below). 19 of the 29 participants with experience in Lesson Study played a leadership role in facilitating lesson study teams, organizing workshops and other lesson study events. The remaining 10 participants observed research lessons and participated in lesson study planning teams.

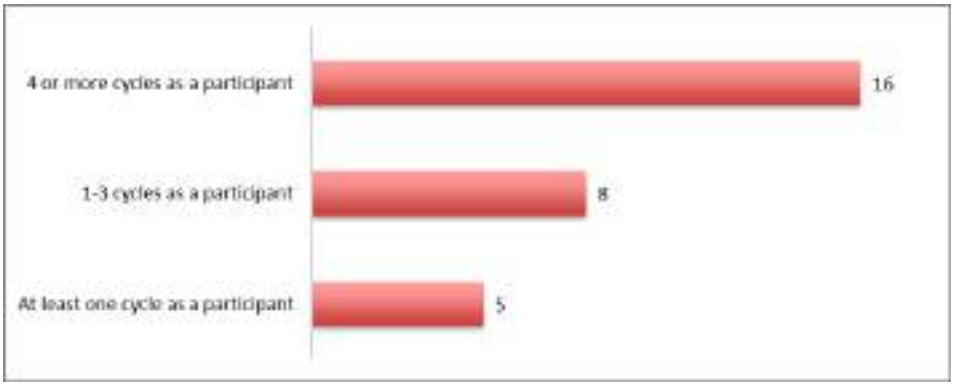


Fig 2: Frequency of experience in Lesson Study

Comprehensiveness of the Programme

The programme on the whole is very comprehensive. It provided a range of learning experiences for the participants and took into account that some participants were more familiar with elementary schools and others with secondary schools. The programme comprises seminars and workshops on mathematics teaching and learning in Japan, Lesson Study in Japan, teaching through problem solving and Kyouzai-Kenkyu on the first day. This was followed with visits to a total of 5 schools to observe lessons and post lesson discussions.

There was special effort on the part of the organizers to provide different kinds and levels of Japanese Lesson Study experiences. Three of the schools were engaged in school-based lesson study – Sugekari Elementary School, Saiwai Elementary School, Ryuo Elementary School. One school had special lesson study organized for Fuzoku teachers – TGU International Secondary School. The last school on Day 5 of school visits on a Saturday provided participants with a cross-district lesson study experience at University of Yamanashi Attached Elementary School. In total, participants had the opportunity to observe 7l math lessons at different grades as well as experienced how lesson study is organized in different contexts and scale.

Table 1 shows the range of schools, the grades, the math topic and the goals of the lessons.

Table 1: Range of schools and lesson observations

Date	School	Grade	Topic	Goal of Research Lesson
21 June	Sugekari Elementary School (School-Based)	6	Area of Composite Figure	Students can think about variety of strategies to determine the area of a composite figure involving circles and calculate the area.
22 June	Sawai Elementary School (School-Based)	4	Division	Students can think about ways to calculate 48 ÷3 using diagrams and their prior knowledge of division.
23 June	TGU International Secondary School (Special LS for Fuzoku Teachers)	7	Graphs (Let's make a graph of motion)	(1) Students will understand That the slope of graph represents the speed. [Knowledge and Understanding] (2) Students will think about how they need to move to create the given graphs and actually create them. [Investigation of patterns] (3)Students can explain the relationship between motions and graphs using appropriate words. [Communication]
		9	Random Sampling	(1) for students to experience and understand the merits of random sampling and develop the disposition to make use of what they learned in their own projects in the future. (2) the improvement of students' ability to use statistics in communication.
24 June	Ryuo Elementary School (School-Based)	5	Volume	Students can apply what they Have learned so far and think about ways to determine the volume of complex figures.

25 June	University of Yamanashi Attached Elementary School (Cross-District Lesson Study)	1	Subtraction	Students will grasp comparison--difference--unknown situation as subtraction situations by relating them to separate--result--Unknown situations. They can represent the situations using pictures, words, and block manipulation.
		6	Division of Fractions	Students reason that the quotient represents the ratio when the divisor is considered as 1 using diagrams and equations.

Support for participants

There was adequate support to participants in the programme. The availability of translation helped tremendously in the learning of the participants. The lesson plans were well translated in detail and participants were appreciative of the hard work of Prof Ted Watanabe from Kennasaw State University in translation. These lesson plans were provided well in advance for participants to read prior to observing the lessons. Participants found the readings provided relevant and referred to them when they wrote their reflections. The interpreter(s) for the observation of lessons and post lesson discussions were excellent and participants could understand the flow of the lessons very well as evidenced by the group project reports. A template on how to write the group project reports was also provided and participants found the template useful. They did not have as much time as they would have liked for discussion to complete their respective group reports.

Participants Learning through the IMPULS Programme

This section describes the rich learning that the participants derived from the programme as shown mainly in their reflective journals. These journals were analyzed for emerging themes about their understanding of Japanese Lesson Study and the teaching of Math through problem solving. The immersion programme also provided a window for participants to experience the culture of Japanese schools and classrooms.

1. **Misconceptions about Japanese Lesson Study**

1.1 **Re-teaching the research lesson**

A key question that recurred in the participants' reflections was their understanding of authentic Japanese Lesson Study. Several participants realized that Lesson Study is not about the perfect lesson and that in Japan, the lessons are rarely taught the second time based on ideas of improvement within a cycle. Knowing this allowed them to set realistic expectations for the potential outcomes of the lesson study process. They became keenly aware that even with re-teaching a lesson with ideas for improvement, it does not allows mean that it will be better.

“Lesson study is not about creating the 'perfect lesson' and authentic Japanese lesson study does not place importance on re-teaching the same lesson. This is a huge misconception that we have at the school I currently teach at” (ID1).

“The perfect lesson plan does not exist. What exists is what you learn” (ID27).

“When discussing how lesson study is lost in translation Akihiko mentioned that *he had observed teachers teaching the same lesson 6 times. This struck me as a little like how mathematics is often taught – through students repeating the same procedure as they work through an exercise. Thus, possibly the teachers were treating lesson study in the same manner as they taught mathematics?” (ID 28).*

“*Knowing there is no such thing as the perfect lesson helps them be realistic about their expectations for a public lesson. It also means that there is always room for growth, even for the most experienced teachers” (ID 14).*

“It is not the goal of Lesson Study to re-teach the lessons, as it is a process of learning for teachers that can only happen when the lesson don’t go as planned, and not a process to create perfect lessons or perfect tasks, because there is no such thing” (ID7).

1.2 Case pupils and interviews after the research lesson

The UK participants realized that what has been advocated in their practice with a focus on three specific case pupils and interviewing them before and after the lesson is not part of Japanese Lesson Study. It was an addition made to the UK version of Japanese Lesson Study. They also realized that the UK version of Lesson Study had the research lesson repeated 3 times.

2. Insights about Japanese Lesson Study

2.1 Kyouzai Kenkyu and the role of Japanese textbooks

Participants were particularly sensitized to the importance of *kyouzai kenkyu* – study of the curriculum and textbooks in the lesson study cycle. One participant called it the “missing piece of the puzzle” in the implementation of lesson study in his home country. The example provided during the seminar of how the Japanese textbook introduced the concept of rate through the investigation of the notion of crowdedness was particularly insightful.

“The study of the textbook goes beyond looking at the problem posed, but also how the problem is posed and positioned to provide opportunities for student to engage in mathematical processes to learn new concepts. This may involve building up the concepts from students’ prior knowledge and considering the choice of numbers to facilitate students’ learning” (ID9).

“This concept (Kyouzai Kenkyu) is one that I find very interesting and important. It is something that is very much devalued in the education system in the USA” (ID13).

“It starts with establishing a “common ground” among teachers: kyozai-kenkyu. This is an extremely important stage of planning, as it is when teachers establish common language among them and engage in a deep study about the lesson topic, also studying curriculum materials. In my

understanding, it is a moment that research in mathematics education comes into action and reaches the classrooms" (ID7)

"I was intrigued by the discussion about the problems presented in the Japanese text book and to spend time looking at the well thought out sequence of problems presented for the development of a concept" (ID16)

The participants became even more aware of the importance of "kyozai kenkyu" when they read the detailed lesson plans provided and observed the discussions following the research lessons and comments made by the knowledgeable others. They realized how little attention was paid to this important phase in the lesson study cycle in their own countries. They also realized how the availability of high quality textbooks helped Japanese teachers in their engagement of "kyozai kenkyu".

"When I think about how little we incorporated research into our lesson planning process as a research lesson planning team it is clear to me how much "kyozai kenkyu" would have improved the lesson that was eventually taught" (ID12).

"Unfortunately, these aspects of lesson planning are missing in many XX schools. Most of the time, teachers pay little attention to the mathematical concepts, the underlying cognitive difficulties and how the design of tasks can be tweaked to support students' learning. They instead focus on the research lesson and think about "innovative" or "interesting" lesson ideas, which may not target students' learning difficulties" (ID9).

They were impressed with the quality of Japanese textbooks. As one participant shared *"Japanese text books are a work of art! Designed and developed by educational experts with input from teachers they are invaluable"... The text books reflect the ideology of learning through problem solving - something that the XX market does not" (ID33).* She was determined to bring these textbook design ideas to her own country.

"I now understand how the textbook is designed to both assist teachers in their instruction via problem solving and to help students to learn through problem solving" (ID25).

"Text books played a very significant role in mathematics teaching in Japan. Initially I was taken aback wondering why teachers follow so strictly to contents in the text books. I finally discovered that the content in the text books has been stringently scrutinized by mathematics experts and educators. Topics in the content are tightly link to promote relational understanding among topics. This could be the reason teachers follow text book content very closely and as the key means for reference" (ID4).

2.2 **Detailed Unit and Lesson Planning**

The participants were surprised with how detailed the unit and lesson plans were. They saw the coherence of the plan to the goals of the unit and how it is elaborated with a detailed scope and sequence. The expanded details allowed the participants to understand the flow of the lessons they observed. They also found the development and treatment of "anticipated pupil responses" within the planning phase to be very powerful.

"Reading the lesson plan, we could understand the amount and depth of the work done by the teachers. This lesson plan was much more thought that what we could call as a usual plan for a lesson" (ID7)

"how thoughtful lesson planning for a research lesson is, especially when introducing a difficult concept to students. Obviously research lessons do not happen all of the time but this is really the way that planning should go for just about any topic that teachers know will be very difficult for students to master" (ID22).

"the deep dive of really analyzing a unit- how different curricula choose to teach it, what units/skills taught previously inform the lesson, and what key takeaways students need at the end of each day- is incredibly important" (ID22).

While participants appreciated how detailed the plans were, some were concerned about whether teachers in their respective countries may find it difficult to write such detailed plans because it is time-consuming. At the same time, they thought it will be worth a try and *"we can stimulate teachers to improve the quality of the lesson plans by convincing them of the advantages and the importance of a detailed lesson plan"* (ID 6). Our UK participants shared how in their context, planning is sometimes done in just one afternoon unlike the 5+ weeks of planning by Japanese teachers.

2.3 Lesson Study as Collaborative Lesson Research

Several participants began to re-think lesson study as lesson research and that the lesson study cycle is like a "learning-teaching research proposal" as you "collect data to answer a kind of research question".

"progressing a rethinking of the Lesson Study model towards Collaborative Lesson Research would coin the authentic components better" (ID5).

It was helpful to me to look at the lesson study cycle as if it is a learning - teaching proposal as stated by Takahashi. It shows that you collect data (observations) to answer a kind of research question. It helps also to focus in your observations on the specific events in relation to the 'research question' (ID6).

"I like the flexible feel of viewing lesson study as a research proposal" (ID28).

"Lesson Research positions the process in a more formal way and makes the process more professional - it suggests real research and a rigorous process. This creates the space for the professionalization of teacher practice and perhaps might prompt teachers to think more deeply about the lesson. Since there is much confusion about what "Lesson Study" truly is, I will definitely be changing my language to call it Lesson Research and defining the process more clearly" (ID17).

"The level of research into lesson study is incredible, how much thought has gone into this type of CPD and learning through problem solving" (ID33).

2.4 Collaborative nature of Japanese Lesson Study

Several participants were impressed by the collaborative nature of Japanese Lesson Study involving everyone in the school. They saw how "*the process of lesson study opens lines of communication and collaboration between educators at all levels within the school or the education system. This collaboration might take place within a school, across a district, between teachers and academics and go as far as to be in dialogue with curriculum writers and educational policy makers*" (ID11).

"In the very first lesson we observed at IMPULS, I was amazed by the level of inclusion of all staff members in the lesson study process. The research lesson was taught in one classroom, but the entire school staff participated in the observation and post-lesson discussion" (ID11).

"I now understand how essential it is that every member of the school team participate in lesson study, with a strong sense of unity. If the ultimate goal is to impact every classroom and every member of the school community, then of course this makes perfect sense". (ID12).

"the presence of all members of staff in both the research lesson and the post lesson discussion had real potential to lead to staff cohesion and a comprehensive understanding of progression of the research topic through the school. There also appears to be a deep sense of mutual respect – perhaps born out of the fact that all members of staff will, at some point, be the teacher taking the lesson" (ID27).

The experience of some participants in Lesson Study is not school-based in nature. Lesson Study is conducted with only a few teams of teachers within a school. In some schools in the UK, Lesson Study is conducted across schools with three teachers coming together from three different schools planning a joint research lesson and trialing the lesson in each of the schools.

2.5 **Bansho – Blackboard work in Japanese classrooms**

The participants saw how carefully planned the board work is in Japanese classrooms and how it presented the story of the lesson as it unfolds with the teacher building upon each of the students' solutions. One board in particular impressed them (see below).

"One particular board was developed in an incredibly impressive manner, containing a combination of mathematical expressions, words and diagrams. This particular teacher also color-coded different shapes being used to solve the problem and was consistent with this throughout the lesson" (ID1).

"to see all the thought and preparation of the board writing: chalk colors used to highlight different aspects, figures that could be magnetically placed in the board to support the writing,... I thought it was very interesting that the use of the board was so carefully planned that in the end of the lesson we could see all four moments of problem-solving. I believe it helps students to see the connections among lesson's mathematical ideas" (ID7).

"Board work is carefully planned, detailed, and presents a clear story of the lesson. There is an importance of colour and established routines e.g. boxing a problem in blue at beginning and reflection in red at the end, use of magnets to identify contributors and pre prepared sheets to post up. Teachers rarely write anything on board that is incorrect. Having such high standards allows the same to be expected of pupils. Teachers model everything in the way they behave, address pupils and write their mathematical work" (ID33).

2.6 **The crucial role of the knowledgeable other**

Participants witnessed how *"having access to good knowledgeable others help make lesson study more effective by synthesising observations presented in the post-lesson discussion and combine with different ideas to provide a clearer picture of student learning"* (ID3). They also realized that the role of a knowledgeable other is a daunting task and that it is ideal to have a knowledgeable other working with a particular school for several years. At the same time, they raised the point that not all the knowledgeable others they heard during the programme were equally impressive compared to others *"who was able to critique the lesson while providing constructive ways in which it (or future lessons) could be improved"* (ID2).

*"But what makes it illuminating was how **the knowledgeable other** referred to the practice questions and highlighted the key difference between 36/3 and 48/3. He highlighted that the practice questions involved dividends that are made up of tens and ones that are divisible by the divisor, e.g., 33/3 and 48/4 etc. The teachers' attention was shifted when they noticed that 48/3 was chosen because 40 and 8 are not exactly divisibly 3. The teachers realized the key point of the lesson was to split the number 48 into two numbers that are divisible by the divisor, which could lead to the long division algorithm"* (ID9).

*"The role of the **knowledgeable other** (and the necessity to have a person skilled in this role) is something that is often discussed by people from other countries trying to implement lesson study"* (ID2).

Others acknowledged that having a pool of knowledgeable others in their countries will be difficult as it is sometimes not easy to find someone with enough authority in the eyes of the teachers.

*"I think there is a need to nurture leaders who can be a **knowledgeable other**. Perhaps, we need to consider how Lesson Study in my country can be brought to a higher level by examining the current*

practices surrounding the Knowledgeable Other" (ID9).

3. New insights into teaching mathematics through problem solving

3.1 Three levels of teaching mathematics

Several teachers in the programme were intrigued by the 3 levels of teaching identified by Japanese teachers as shared by Akihiko Takahashi during the expert seminar. At level 1, the teacher tells; at level 2, the teacher explains meanings; and at level 3, the teacher provide students with opportunities to understand basic ideas and support their learning so that they become independent learners.

"One idea was the "three levels of teaching". Hearing about identifying teachers like Level 1 teacher, Level 2 teacher and Level 3 teacher was quite new. Not because of the ideas behind it, but the actual use of this classification when talking about teaching" (ID7).

"I appreciate the discussion today around level three teachers. Being a teacher that is able to design a lesson so that students can learn is by far the most effective teacher. This seems like a level a teacher can never fully master. Designing such lessons provides endless room for a teacher to study the craft and aspire to get better" (ID14).

"The 3 levels of teaching within Japan intrigued me and it is something I think that UK is lacking and the subtle differences between a Level 2 and Level 3 teacher and the fact that in Japan the mathematics is seen as between student and teacher rather than "behind" the teacher and not always accessible by the student (This is something I completely believe in but I am not sure how many teachers in the UK understand this notion?)" (ID 30).

3.2 Planning with pupils' misconceptions in mind and for different entry points of students

Participants realize that teaching math through problem solving begins with careful planning with pupils' misconceptions in mind that will allow for discussion during the lesson. This careful planning involves careful choice of the problem for discussion and providing for differentiation not in terms of having different expectations for students but planning for different entry points of students at the beginning of the lesson.

"how Japanese teachers approach the different achievement levels in the classroom: instead of thinking about different tasks for "different students", the teachers consider that the problem should have the same goal for every student, however it could have different "entry points", depending on each student. I consider this very important because it shifts the perspective of "for different students, different tasks" to a perspective of embracing differences and, together, reaching the same goal (which emphasize the role that each student have in learning together, within the classroom) ID7

"Clearly the thinking about misconceptions and how a misconception can be translated into purposeful understanding is very powerful"(ID23).

"The quote - If there is no room for misconceptions then there is no room for discussion - stood out

to me" (ID32).

"Airing out these misconceptions and dissecting why they are not so removes the need for memorizing "the way things are" and instead allow mathematicians to internalize it" (ID14).

3.3 The structure of Math problem solving lessons

The research lessons that the participants observed were "*all mondai kaiketsu gakushu and all were organized into four main moments: introduction posing task (hatsumon); independent problem-solving; whole class discussion (neriage); and summing up (matome)"* (ID 7). Unlike the math lessons in their countries, they realized that "*the goal of the math problem solving lesson is "not on the 'answer' to the problem, but on discovering different methods for solving a task*" and to deepen the understanding of a concept.

"The goal of the lesson is not solving the problem but building new knowledge by solving the problem. Therefore, the problem and its presentation were generally carefully designed to direct the student in some way to use a strategy making use of the expected knowledge, but without directly giving him this knowledge". ID10

"Japanese problem solving is not problem solving as we know it. Finding the answer is not the aim, but finding routes to the answer and the careful explanation of those routes is key". ID33

They saw how in problem solving lessons,

"students were encouraged to adopt a problem solving stance and reason mathematically about new challenges, making sense of them through exploration as well as thoughtfully led class discussions that seek to reach consensus on successful strategies. Students forge connections with prior learning, not through reminders from teachers, but by thinking, "what do I already know that might help me solve this new problem?" The students help create the learning, and in so doing, they seem to take responsibility for their work". ID11

"They also realise that in order to implement such problem solving processes in the classrooms in their respective countries, the "classroom culture in many math-classrooms should change from 'answer-centered' to 'mathematical thinking'" (ID 6).

One participant shared that until she has seen the neriage (discussion) phase of a research lesson that she truly realized the importance and structure of this phase and that is not just a "show and tell" (ID1) - an importance not yet seen by others in her country. Fujii (2016) identified this phase as the most difficult phase for the teachers to deal with and the participants witnessed during their observations of the research lessons that "*teachers don't lead but instead ask for clarification, and multiple explanations. The clarity of language and explanation is extremely high*" (ID33).

"As Akhito Takahashi stated on the first day of the program, it refers to kneading or polishing in pottery, where different colours of clay are blended together. This serves as a metaphor for the considering and blending of students' own approaches to solving a mathematics problem. Moreover, it provides an opportunity for teacher and student to together model how students should communicate mathematics both orally and through writing work" (ID28).

3.4 **The selection of the problem for a Math lesson**

The participants realized how critical the selection of the problem for Math problem solving lesson was. The choice of the problem for the hatsumon phase of a math problem solving lesson has to be *"intentional so that the learnings from the research lesson can go beyond problem selection"* (ID14). The participants realized that if the lesson does not start *"with a meaningful problem, it would be difficult for the discussion about the research lesson to reach a level deeper than the problem itself"* (ID14).

"A lot of thought needs to be put into creating the perfect problem for students to solve. A great problem not only allows for multiple ways/strategies for solving a problem, but also is purposefully crafted to highlight and challenge possible misconceptions that may arise for students" (ID22).

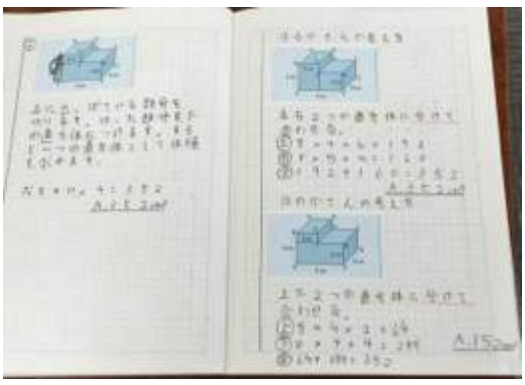
3.5 **Students' Journals**

Participants were surprised to find students writing a journal of their learning at the end of each lesson. They also witnessed how *"time within a lesson is given for these students to reflect upon the lessons even at times when there was not enough time"*. They realize how important this step is in the practice of Japanese lessons with the reflection covering various questions such as *"What you've come to understand?" "What have you noticed?" "What do you want to examine next?" and "What you thought as you listened to your friends' idea?"* (ID25).

"The practice of writing journal or reflection in every lesson was new to me especially being introduced to students at a very early stage, even at grade one. Such good practice compelled students to think and make a summary of what they have learned" (ID4).

"I found very interesting that this reflection could highlight not only mathematical ideas, but any aspect that students feel that were important (e.g. the reflection can be about learning with peers, the confidence felt when solving the problem ..)" (ID7).
"I have a theory that the reflections written at the end of each lesson are key here. I am beginning to feel that pupils are well trained in analysing their own learning, can construct a truthful and honest reflection on their learning, and will absolutely give true feedback to their teacher" (ID33).

What they found also interesting was that the students chose which of their friends' solutions they will record in their notebooks only after the whole class discussion ended did. They were also impressed with how much pride Japanese students take in their notebooks and found them immaculate (see below)



4. Glimpses into the culture of Japanese schools and classrooms

Many of the participants have not been to Japan to observe schools and classrooms. While the IMPULS programme is intended for participants to examine Japanese Lesson Study and Math problem solving lessons, the opportunity to visit several schools in different localities and observe lessons provided them with glimpses into the culture of Japanese schools and classrooms. Several expected the "classroom environment to be serious and very silent" and Japanese teachers as "very serious and strict". But they were proved wrong.

"As soon as we enter a Japanese school and classroom, we are embraced by a joyful environment, where "kids are kids". Students talk and laugh with each other as well as with the teacher. I could feel that classroom norms were solidly established, as students seem to understand when was time to talk and when silence was needed to work, without any particular indication from the teacher" (ID7).

"On the trip I assumed that the students would be learning by rote in silence but I was taken aback with how much they loved maths and their vocal enthusiasm during the lessons" (ID24).

It was clear to participants that in Japanese classrooms, both *"the teacher and students completely understood their roles at each stage of the lesson*" (ID25). The students seemed to be "*very aware of their own responsibility and in their own learning process"* (ID7). The pupils were "*not afraid to question their teacher and peers; they also have the confidence to state that they are lost and need some guidance* (ID33).

"I was really struck with the relationships between teacher and students. … The nurturing of the individuals within the class was most evident with the youngest grades, the teacher slowly building up their confidence to speak about their thoughts; they talked to each other about their ideas, recorded solutions in their books and felt supported if they made mistakes or had misconceptions" (ID26).

"Japanese teachers and students [and possibly parents also] appear to share a commitment to the same long term learning goals. Threading through these shared goals is the culture of joint responsibility towards achieving them. I think it is the mutuality of endeavour that engenders a sense of the importance both of what is being studied by students and the teacher's role in this activity. This in turn may foster the belief that all will work hard to achieve these joint goals. This was evidenced, for example, in the complete absence in all observed lessons of students being 'told off'"(ID28).

5. Prior Expectations of Learning and Realization of Learning

Our survey asked participants what they expected to learn during the immersion programme and how much did they learnt after the programme on a five point scale, 1 = Not at all ; 2 = A little; 3 = Some ; 4 = Quite a bit ; 5 = A lot. All the participants started with high expectations of their learning from the programme on the following aspects with a minimum mean score of 3.55 and a maximum mean score of 4.52.

A1: How to lead the development of LS goal and research theme.
B1: Writing a useful lesson plan
B2: Developing math units and lessons
B3: Math subject matter knowledge
B4: PCK of teaching math

B5: Analyzing/studying curriculum materials
B6: How to build students' problem solving
B7: Anticipating student responses
B8: Students' math reasoning
B9: Strategies for making thinking visible
B10: Support for struggling learners
B11:Build students' math habits of mind and practices
B12: Build a classroom LC
C1: How to observe students carefully
C2: Collecting data on student thinking to inform instruction
C3: Analyzing and interpreting verbal student comments
C4: Analyzing written student work/ responses
D1: Organizing a successful post-lesson debriefing session
D2: How to provide comments as external commentator
E1: How to lead LS
E2:How to facilitate LS discussions
E3: How LS is conducted in another country
E4: How LS is conducted in different educational contexts
E5: Build connections among educators at multiple levels of education
E6: Supporting participants to have powerful/effective LS experience
E7: Organizational/structural supports for LS
E8: Strategies for working effectively in a LS group
E9: How teachers learn from participation in LS
F1: Japanese approaches to the teaching of Math
F2: Cultural influences on math T&L
F3: A typical school day at a Japanese school
F4: Knowledge about the Japanese educ. system in general
F5: What other IMPULS participants are doing with LS

Figure 3 shows the participants' responses before and after the programme.

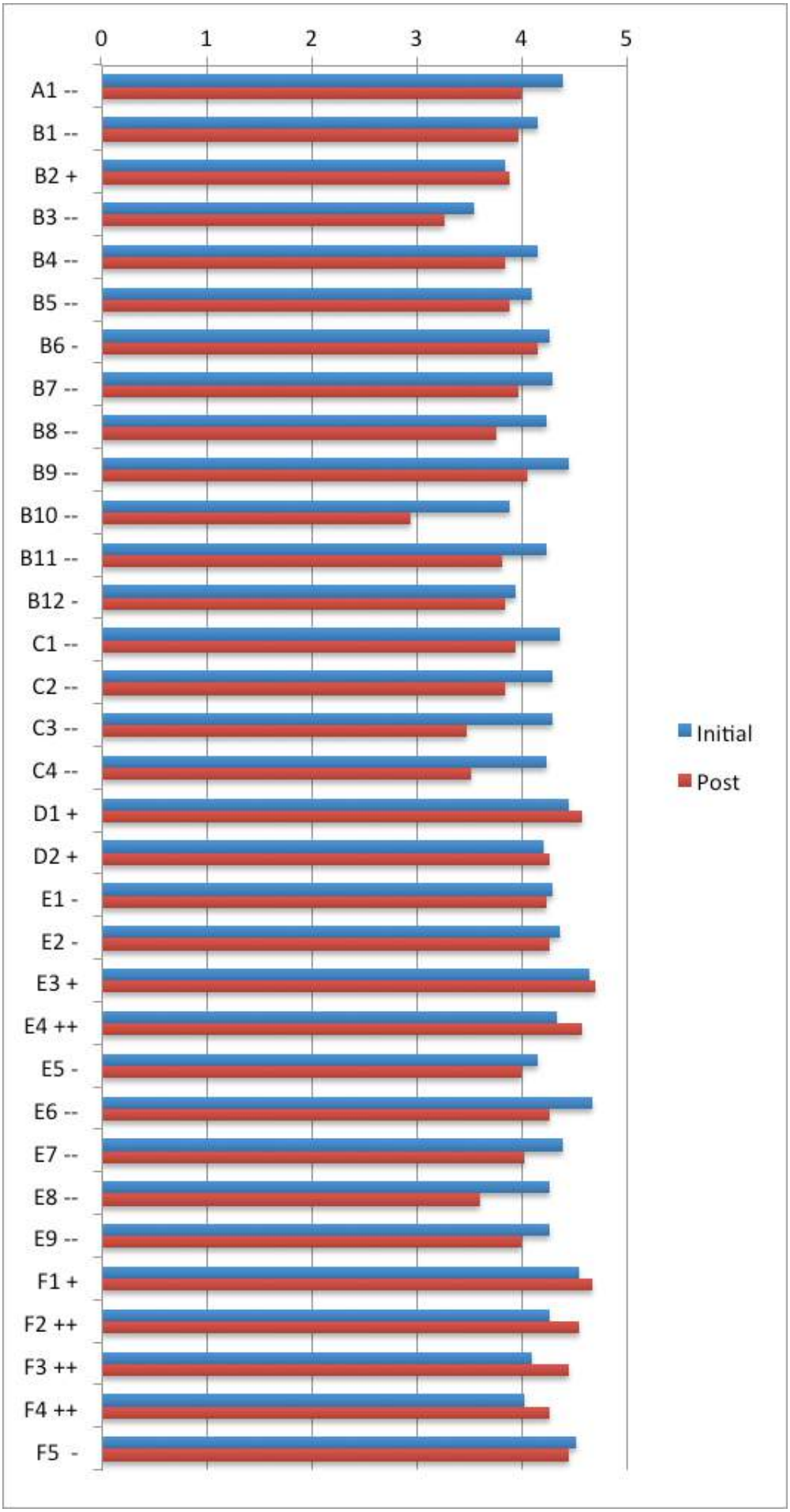


Figure 3: Participants' Expectations Prior and After the Programme

The following aspects of Japanese Lesson Study and Mathematical problem solving lessons showed the realization of the learning of participants either at or above their expectations:

B2: Developing mathematics units and lessons
D1: Organizing a successful post-lesson debriefing session
D2: How to provide comments as external commentator
E3: How LS is conducted in another country
E4: How LS is conducted in different educational contexts
F1: Japanese approaches to the teaching of Math
F2: Cultural influences on math teaching and learning
F3: A typical school day at a Japanese school
F4: Knowledge about the Japanese education system in general

These are aspects that could be visibly observed throughout the programme.

Several aspects though fell short of expectations and these included:

A1: How to lead the devt of LS goal and research theme.
B1: Writing a useful lesson plan
B3: Math subject matter knowledge
B4: PCK of teaching math
B5: Analyzing/studying curriculum materials
B7: Anticipating student responses
B8: Students' math reasoning
B9: Strategies for making thinking visible
B10: Support for struggling learners
B11: Build students' math habits of mind and practices
C1: How to observe students carefully
C2: Collecting data on student thinking to inform instruction
C3: Analyzing and interpreting verbal student comments
C4: Analyzing written student work/ responses
E6: Supporting participants to have powerful/effective LS experience
E7: Organizational/structural supports for LS
E8: Strategies for working effectively in a LS group
E9: How teachers learn from participation in LS

In examining the list, most of these aspects are connected with helping participants to understand more the math in the lessons observed as well as learning the skills to examine student learning with greater depth. The largest decline in realization of expectations is in:

B10: Support for struggling learners
C4: Analyzing written student work/ responses
E8: Strategies for working effectively in a LS group

The list of aspects were not as visibly observed during the programme and needed to be foregrounded more in discussions.

6. Puzzling thoughts and remaining questions of participants

In spite of the powerful learning in the programme, there were still remaining questions that continue to puzzle the participants. Some of these included:

(i) how to frame observations, which are the observation cue points, when do they decide as

evidence etc (ID5)
(ii) how the post lesson discussion main ideas to change or improve will impact or be incorporated in future lessons (ID7)
(iii) how students with learning differences or who struggle in school are given entry points; how were these students supported in the following weeks? Are there interventions or small group instruction for struggling students? (ID13)
(iv) what kinds of supports do teachers typically give to students who are active and need movement in their learning? (ID13)
(v) what sort of formative assessments does the teacher give in order to assess learning? Are formative assessments intentionally excluded from lesson study lessons? (ID13)
(vi) how the feedback from a research lesson is used to support the teachers and schools to improve their pedagogical strategies.? (ID26)
(vii) How has teachers' ability to use questioning so effectively been developed? Has it come from the text books? Is it taught, observed, learnt through experience? (ID33)

7. Recommendations for future planning of the IMPULS programme

7.1 While all the participants have learnt a great deal from the IMPULS programme, they found the programme very packed and would have liked more time for discussions about each research lesson prior to observation as well as time to discuss their observations after the research lesson. There were a few sessions provided but they found them insufficient. They also needed more time to write their reflections and to meet together in small groups for their group reports. They appreciated the expert led seminars but asked for more small group discussion so that they can benefit from each other's experience and expertise. They also wanted more time to be given to the analysis of math curriculum materials related to topics taught during research lessons. One concrete suggestion from a participant was to start the programme mid-week rather than a Monday allowing them two Sundays and more time for reflection.

I would have like more time to work on our group report which was a great occasion for our group to discuss and exchange. For our group, it would have been easier and even more fruitful.. to really collaborate.

Would have been nice to always have group debrief after a lesson and not wait in a day.

Some time could be devoted to kyozaikenkyuu, guided by Japanese educators, and perhaps the beginnings of a research lesson would emerge.

If possible, I would suggest some type of rest period built into the day, sometime in the afternoon. There were many days I wished I could have just taken a quick nap at the hotel before continuing with the rest of the day's activities, but we often had to push through very long days.

it may have been more useful for us to have been studying textbooks

7.2 Also scheduling 2 lessons a day was difficult was some participants. Having one lesson a day may allow some time for participants to meet with the research lesson teacher for further discussion. They would like to know more about the planning process from the perspective of the research lesson teacher.

The only thing that I found difficult was observing two lessons back to back, as it was not only draining but slightly muddled my thinking at time.

One slight improvement would be to only have one lesson each day, although this is a small point.

7.3 Cutting back on the number of school visits and giving more time to more hands-on activities such as analyzing math curriculum materials, developing observation skills and small group discussions may provide more balance in the programme. It would cater to the varying backgrounds of the participants as some have limited lesson study experience and some do not have a mathematics background. Perhaps there are just too many lessons to observe. A total of 7 lessons with sometimes two lessons within a day while interesting may prove too much for some participants who are still suffering from jetlag. This could be a case of "less is more".

Concluding Remarks

In spite of the intensive jam-packed 10 days with long days of activities, each participant left the programme with deep gratitude to the IMPULS organizers and the expert faculty from Tokyo Gagukei for giving them a unique and memorable experience.

Thank you very much for an incredible experience - one which I believe will transform the approach to problem solving lessons in my region.

As we return to our countries, we return with the certainty that we have observed and participated in moments of Lesson Study in its authentic context, experience that we can share with our colleagues at school or in the academic field.

The IMPULS programme has inspired the participants to bring about change in how they implement Lesson Study in their respective countries. They would like to scale their lesson study efforts to be whole school based, involve more their administrators, use collaborative lesson research in their schools, treat the research lesson as a lesson proposal, work on improving the role of knowledgeable other and have one for every research lesson, distinguish the role of the facilitator and knowledgeable other, have a school wide research theme with monthly research lessons, study the Japanese textbooks to learn how to implement problem solving in math lessons, work on giving constructive criticism rather than just praise the teacher, do kyozai kenkyu on the topics for the research lessons, incorporate essential features of lesson study in initial teacher training programmes etc. Through the action agenda of the participants in the respective countries, the impact of IMPULS goes beyond the powerful learning within 10 days in Tokyo. In the words of one participant, "this is a marvellous program and it should be continued"

Annex 1

List of Participants for Lesson Study Immersion Program 2016

June 20 - June 27 in Tokyo, JAPAN

External Evaluator ;
Lee Kim Eng, Christine, Ph.D. (Email: christine.lee@nie.edu.sg)
Associate Professor, Curriculum, Teaching and Learning (CTL), National Institute of Education, Singapore

	Name		Country	School/ Department
1	Ms	Felicity Ames	Australia	South Geelong Primary School
2	Dr./ Ms.	Susie Groves	Australia	Deakin University
3	Mr.	Marlon Ebaeguin	Australia	Melbourne Graduate School of Education (originaly from Manila,
4	Mr.	TEH KIM HONG	Malaysia	Institute of Teacher Education, Penang Campus
5	Dr./ Ms.	Sui Lin GOEI	Netherlands	Windesheim University of Applied Science
6	Dr.	Gerrit Roorda	Netherlands	University of Groningen
7	Ms	Cristina Maria da Silva Morais	Portugal	Externato da Luz (elementary school)
8	Ms.	Marisa Alexandra Ferreira Quaresma	Portugal	Instituto de Educação da Universidade de Lisboa
9	Dr/ Mr	CHOY Ban Heng	Singapore	National Institute of Education
10	Dr./ Mr.	Stéphane Clivaz	Switzerland	Lausanne University of Teacher Education
11	Ms.	Brigid Brown	US	Acorn Woodland Elementary
12	Ms.	Hanna Sufrin	US	Acorn Woodland Elementary
13	Mr.	John Christopher A. Aragon	US	Acorn Woodland Elementary
14	Ms.	Kari Laux	US	Acorn Woodland Elementary
15	Ms	Crystal Ramirez	US	Daniel Webster Elementary, San Francisco Unified School District
16	Ms.	Marna Wolak	US	Sanchez Elementary School
17	Mr	Brent Jackson	US	Santa Rosa City Schools
18	Ms.	Rebecca Setziol	US	Daves Ave Elementary
19	Ms.	Megan Mahoney	US	Daves Ave Elementary
20	Ms.	Rebecca Zisook	US	Helen C. Peirce School of International Studies
21	Dr./ Ms.	Shelley Marie Terzian	US	Helen C. Peirce School of International Studies
22	Ms.	Trinity Thompson	US	Harlem Village Academies East Elementary
23	Mr	Bob Sawyer	UK	St Thomas of Canterbury Teaching School – Learning Unlimited
24	Mr	David Wylde	UK	Riverside school
25	Mr	Derek Robinson	UK	Bushop Luffa CE School
26	Ms.	Jan Parry	UK	Independent consultant
27	Ms.	Pauline Tyson	UK	Oxford Brookes University
28	Ms.	Sheila Evans	UK	Nottingham University
29	Mr	David Freeman	UK	Harris Foundation
30	Mr	Dean Rowley	UK	Kesgrave High School
31	Mr	Graham Charles	UK	Salop Teaching Alliance, Church Stretton School
32	Mr	Paul Rowlandson	UK	Trinity Academy Halifax
33	Ms.	Rachael Horsman	UK	Cambridge Maths