Lesson Study as a tool for teacher learning: the context of combinatorial reasoning problems

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1. Introduction

In the last ten years there has been a growing interest in Japanese Lesson Study (Stigler & Hiebert, 1999). Lesson Study experiences are reported from Hong Kong and Sweden (named Learning Studies), Germany, and the US (C. C. Lewis, 2002; C. C. Lewis & Hurd, 2011) and the Netherlands (N. C. Verhoef, Coenders, van Smaalen, Pieters, & Tall, 2015; N. C. Verhoef, Coenders, van Smaalen, & Tall, 2013). In Lesson Study participating teachers choose a topic and plan lessons collaboratively, one teacher implements the lesson in class and student learning is live observed by all participants, and finally the observations are discussed (C. C. Lewis, Perry, & Murata, 2006). The focus is on student learning, and this creates teachers' awareness on mathematical knowledge of teaching and learning. Lesson Study is chosen as a teacher learning strategy because research shows that within a context like Lesson Study, changes in knowledge and beliefs are to be expected (C. C. Lewis, 2009). The aim of this study is to investigate the effects of Lesson Study on Dutch mathematics teacher learning with the focus on combinatorial reasoning problems. Combinatorial reasoning problems (with permutations and combinations) are difficult for students; they feel uncertainty to solve this type of problems. In this study we choose Lesson Study alerting the mathematics teachers to focus on students' reasoning to set up counting problems. We relate teacher learning in terms of external influences, classroom practices and internal knowledge, beliefs and attitudes.

2. Theoretical framework

2.1. Lesson Study

Lesson Study originates from Japan, where it is a leading approach for teachers' professional development. Teachers collaborate in a team with the intention to probe students' learning processes (Lewis, 2009; Saito, 2012). In a Lesson Study team, teachers, under the supervision of a process organiser, collaboratively improve teaching and learning assisted by an experienced teacher trainer in the field of study. First the team analyses the way they introduced a certain topic. Experienced problems are discussed and this leads to new student and teacher activities. In the next phase, the so called research lessons are planned. In the research lessons the new approach and activities are implemented in class by one of the participants while the others live observe the way the students learn. Then the different observations are discussed by the team. Finally, on the basis of these discussions the activities are revised, and the planning, implementation, observation and discussion is repeated as shown in Figure 1 (Stepanek et al. (2007, p. 3)).

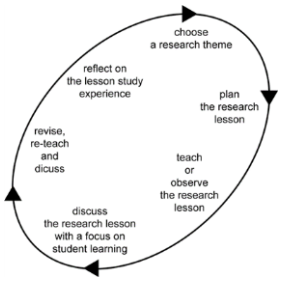

Figure 1. Lesson study cycle (adapted from Stepanek et al. (2007, p. 3))

Members of the Lesson Study team, and as much as possible colleagues and other interested persons live observe the research lesson (Saito, Hawe, Hadiprawiroc, & Empedhe, 2008). The focus is on observing the students, not the teacher (Oshima et al., 2006).

2.2. Teacher learning

In this study we focus on the content knowledge, curriculum knowledge and pedagogical knowledge aspects of Shulman's (1987) Pedagogical Content Knowledge (PCK).The Interconnected Model of Teacher Professional Growth (IMTPG) (Clarke & Hollingsworth, 2002) as depicted in Figure 2, is used to analyse teacher learning.

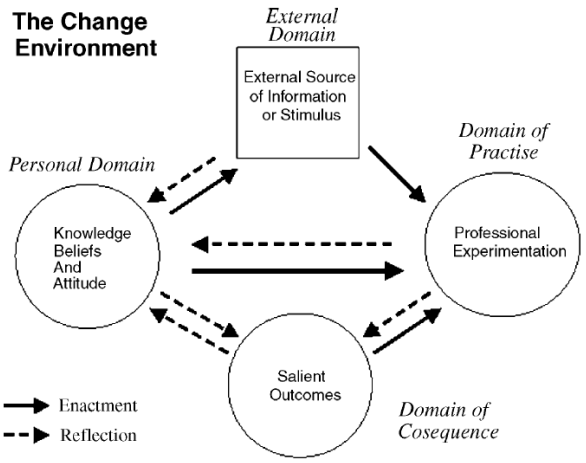

Figure 2. The Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002)

The IMTPG takes teacher change to be a learning process and suggests the mechanism by which this learning might occur: in recurring cycles through the processes of 'reflection' and 'enactment' in four distinct domains. Three of these domains are situated in the teachers' daily world, the fourth (the External Domain) is outside this daily world. Teachers' knowledge, beliefs and attitudes are situated in the Personal Domain (PD). The External Domain (ED) is where a teacher meets new ideas. In the case under discussion the ED consists of specific literature, the live observations and the discussions. The Domain of Practice (DP) involves all possible kinds of teacher classroom experiences, in this study the implementation of the research lessons. The Domain of Consequence (DC) focuses on the student learning results. This domain is coloured by teacher's expectations beforehand. Clarke and Hollingsworth (2002) emphasized the effect of a change in one domain as a sequence of changes in the other domains. They identified temporal changes named 'change sequences'. When the change is more than momentary, this is seen as professional growth and the associated change sequence is termed a 'growth network'.

3. Method

3.1. Participants and context of the study

The participants were seven Dutch mathematics secondary school teachers from different schools. Two of them participated three year in the Lesson Study team, one of them participated two year in the Lesson Study team. Two members of the university completed the team: a mathematician of the applied mathematics department (the chair) and a researcher. The Lesson Study team met three weekly at the university. The teachers were given time (half a day weekly) from their school management to participate in the Lesson Study team. The first teaching of the two successive research lessons took place at the end of October 2013 with 28 students aged 15. The second revised teaching took place in another school two weeks later, with 24 students. The researcher distributed the scientific literature with regard to research outcomes related to teaching and learning counting problems (Batanero, Navarro-Pelayo, & Godino, 1997; Eizenberg & Zaslavsky, 2004; Hadar & Hadass, 1981; Lockwood, 2011). Particulars of the Lesson Study participants are shown in Table 1.

Table 1. Description of the participants

	Work experience in 2013	Degree + extra information
Alan	28 year	MSc mathematics + MSc education; mathematics team leader
Bill	2 year	MSc philosophy + MSc education, lower level to upper level high school
Cody	6 year	MSc technics + MSc education, mostly upper level high school
Don	20 year	BSc mathematics + MSc education, mostly upper level high school
Eli	2 year	MSc mathematics + MSc education, lower level to upper level high school
Fred	23 year	MSc mathematics + BSc education, lower level to upper level high school
Gus	3 year	MSc mathematics + MSc education, lower level to upper level high school

The first Lesson Study cycle consisted of several planning meetings but only during the last meeting teachers completed a learner report. The research lessons lasted 50 minutes each. The students were divided in groups - four students each – strong, middle and weak student groups.

3.2. Research instruments

The research instruments consisted of teacher leaner reports based on the video-taped Lesson Study cycle aspects: preparation, teaching and live observation with discussion / reflection and evaluation. The teachers answered a combination of open, half-open, and closed questions about the learning outcomes, They added the context in which the learning experiences occurred and their intention(s). This combination of the questions should provoke and support teachers to report in detail their learning experiences. The design of the learner report was inspired by the work of De Groot (e.g., Van Kesteren (1993)), and Endedijk and Vermunt (2013). We distinguished four versions of the learner report each tailored to address characteristics of a specific Lesson Study activity: collaborative preparation (P), teaching (T) or live observation with post-lesson discussion (O), and evaluation (E). In all learner reports the teachers were asked to highlight what happened and to

describe **what** they learned and **from what** they learned: exactly what happened, who was involved, did you expect this and why, what were the effects on you personally, and did you design new plans based on this experience?

3.3. Procedure and data analysis

The learner reports of the seven secondary school teachers who participated in this study were collected between September and December 2013. The participants received instructions about the learner report. The participants reported a self-chosen learning experience by completing a learner report two times in a university meeting in the first Lesson Study cycle: firstly after the collaborative preparation and secondly after the teaching (of two successive research lessons), observations and discussions.

The analysis involved several stages. The data were structured and paraphrased in order to make these accessible. Teachers' written answers were marked by condensed statements representing what was learned and from what was learned. The 'what was learned' statements were categorized in aspects of mathematics teaching methods: 'not working', 'formulas - without student understanding', 'focus on one single context' and 'focus on different contexts'. The 'from what was learned' statements were categorized in preparation, teaching, observation, discussion and evaluation. The researchers summarized these results in: "What was learned" and "From what was it learned".

4. Results

Table 2 reports 'what' and 'from what' the teachers learned in the Lesson Study cycles in phases. The first column holds teachers. The second column reveals 'what' the teachers learned. The third column holds 'from what' the teachers learned in phases: preparation (P) continued by teaching (T1) or observation with discussion including preparation (O1) in the first Lesson Study cycle, and teaching (T2) or observation with discussion (O2) continued by final evaluation (E) in the second Lesson Study cycle. The fourth column shows aspects of teachers' growth network in terms of IMTPG domains.

Table 2. Teachers' learning activities in the two Lesson Study cycles on counting problems

	I learned that…	**from..**	**IMTPG**
Alan	… my students, with me being unaware, apply tricks and a difference between choosing and ordering	P	PD
	… when students see numbers in an exercise starting multiplying, without any meaning	O1	DC
	… students learn from acting out a counting problem	O2	DC
	… visualizations are important for student understanding	E	PD
Bill	… I should enrich lessons with pictures / systematic notes	P	ED
	… the teacher should help students tackling counting problems showing practical applications	O1	DC
Cody	… student need to count systematically as a basis to learn combinatorics	P	ED
	… the supposed importance of imagining instead of drawing pictures	O1	DP
	… enthusiast students have no idea whether their approach is correct	O2	DC
	… visualizations and plays are important tools to understand counting problems	E	PD
Don	… certain approaches need to be developed far for (students) to see that the chosen approach does not work	P	ED
	… it is hard to teach students by letting them discover	O1	DP
	… students are uncertain, unable to explain what they did	T2	DC
	… suitable practical examples are hard to find	E	ED
Eli	… students are not capable yet to systematically write out	P	PD
	… students first try to work everything out in mind before writing out any part and continue	O1	DC
	… there are many ways to look at a counting problem, students should be made aware - no more problems	E	ED
Fred	… the importance of systematic counting and the way to write this out, I will give more attention to that	P	ED
	… acting out a situation really helps students to understand the counting problem and the differences	O1	DC
	… students need to systematically write out all possibilities to feel certain: solution is correct	O2	DC
	… students should be able to switch the point of view, too different problems are not helpful	E	PD
Gus	… it is hard to predict student reaction on open questions	P	PD
	… open questions are helpful to reveal thinking processes, hard to relate concrete problems	T1	DP
	… different students learn completely other things	O2	DC
	… students should be able a visualization by situations	E	ED

At the preparations the teachers decided to start with thirteen different counting problems, asking the student groups to order them and explain their ordering (Batanero, Navarro-Pelayo and Godino's 1997). It proved hard to predict what

difficulties students would encounter when dealing with combinatorial reasoning problems. The students' arguments provided the teachers a lot of insight regarding their own view on what their students are capable of and how they can investigate student thinking processes in terms of ordering and replacement. Almost all the teachers concluded in the evaluation of the first lesson that the chosen approach had not worked, but were very pleased with the conclusions they could take from it, resulting in an adjusted second plan with a focus on the visualization of the problems. None of the teachers had anticipated this to be a vital part of the lesson plan at the beginning of the Lesson Study. The teachers said no longer to use their previous approach with regard to combinatorial reasoning problems but decided to focus on one single context stimulating students' imagination. In the second Lesson Study cycle the context 'offering five chairs to three people' was used in the first research lesson. A comparable situation of choosing three out of five people to be a chairperson, a secretary and a treasurer was used in the successive second lesson. When discussing the observations, the teachers became aware of the power of comparing situations in different contexts and of students playing out the situation.

Looking at the domains in the IMTPG, it becomes clear that the preparation of the Lesson Study made the teachers aware of the fact that students use tricks, highlighted in their textbooks, to solve counting problems. The teachers discussed their classroom practices of students' use of not understandable formulas (DP) being aware of students' lack of systematic counting and writing out (ED). The live observation reveals teachers' classroom experiences and student learning as well as the importance of imaging (DP). Teaching made the teachers aware of students' uncertainty and the positive effects of playing out (DC). The reflection and evaluation show teachers' awareness with the focus on carrying out the collaborative prepared lessons (PD) and the reasoning about teaching and learning strategies (ED).

This study in a Dutch Lesson Study context reveals the advantage of visualization and playing out combinatorial reasoning problems. Our research outcomes show that the Lesson Study approach is a flexible approach based on daily complex and different classroom practices. Lesson Study promotes the focus on student thinking and learning, instead of the best learning materials or teaching methods. According to Saito (2012) key points and practices required to develop skills in observing and interpreting what happens in the classroom are also still largely unspecified. Models that specify the connections between the observable characteristics of Lesson Study and instructional improvement, would therefore be useful (C. C. Lewis et al., 2006). The Dutch experiences demonstrate that it is advisable to limit the number of participants in Lesson Study teams. Too many participants hinder the quality of the discussions. Scaling-up the Dutch Lesson Study experiences is complex. Firstly, the school managers who are willing to stimulate the scaling-up of Lesson Study supporting teachers by giving time to plan collaboratively, to visit other schools and to reflect in the university meetings. Secondly, the Lesson Study experts who are able to organize the Lesson Study and distribute scientific literature to professionalize the teachers. Thirdly, the teachers themselves who are interested in searching their own classroom practices in collaboration with colleagues.

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