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The impact of Lesson Study professional development on the quality of teacher learning

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Highlights

1. Three patterns of teacher learning could be identified: meaning-oriented, application-oriented and problematic learning.
2. A reliable instrument to measure these teacher learning patterns was developed.
3. The study contributes to our understanding of the influence of teacher professional development on teacher learning.
4. Lesson Study has a beneficial effect on the quality of teacher learning.
5. Lesson Study has the highest impact on improving teachers' meaning-oriented learning.

Abstract

This paper aims to increase our understanding of the impact of Lesson Study (LS) on the quality of teacher learning. It draws on longitudinal and cross-sectional data from three waves of data collection from 214 teachers engaged in LS during one full school year. The findings showed positive effects of Lesson Study on meaning-oriented and application-oriented teacher learning and a negative effect on problematic learning. Less experienced teachers showed the highest gain in meaning-oriented learning. The paper contributes to advancement of our theoretical understanding of teacher learning as it provides evidence of mechanisms through which professional development impacts teacher learning.

Keywords

Teacher learning; professional development; learning patterns; professional learning; Lesson Study

Introduction

Stemming from practice over many decades in Japan, Lesson Study (LS) has gained rapid popularity outside Japan during the last decades (Dudley, 2015). LS offers a well-developed set of principles and procedures for supporting teachers' professional learning, focusing on the planning and analysis of 'research lessons'. It has several components: identifying improvement aims; formulating hypotheses and goals; joint research lesson planning; teaching and observing research lessons; post-research lesson discussion; and passing on the knowledge gained. Although the beneficial effects of LS on teacher learning outcomes are well documented, Xu and Pedder (2015) claim there is a lack of studies exploring why and how teachers learn in the context of Lesson Study.

LS seems to integrate many features of effective professional development (PD) programmes suggested by prior research: it addresses problems of practice; teachers focus strongly on students' learning; preferred instructional practices are modelled and shared; it involves active teacher learning and teacher inquiry; it creates professional learning communities; the setting is appropriate to school-based goals; and learning opportunities are on-going and sustainable (e.g. Borko, Jacobs, & Koellner, 2010; Desimone, 2009; Van Veen, Zwart, & Meirink, 2012).

In this paper, we will focus on one of the possible mechanisms that bring about teacher learning outcomes: the quality of teacher learning processes. We will take a particular perspective, a learning patterns perspective, on teacher learning in PD programmes (e.g. Vermunt & Donche, 2017). We will view LS as an example of a PD model that meets many of the characteristics derived by Borko et *al.* (2010) and examine the impact of such a powerful model on the quality of teacher learning.

Our main hypothesis is that LS works because it improves the quality of teachers' learning processes and patterns. We conceptualize teacher learning processes as the

cognitive, regulative, affective and social learning activities that teachers use to learn something. Learning patterns are viewed as a coherent whole of learning activities that learners usually employ, their beliefs about learning and their learning motivation, a whole that is characteristic of them in a certain period of time (Vermunt & Endedijk, 2011). Three teacher learning patterns are discerned in this paper: a meaning-oriented learning pattern, an application-oriented learning pattern, and a problematic learning pattern. Our more specific main hypothesis is that LS leads to more meaning-oriented teacher learning, more application-oriented learning and less problematic learning.

This study aims to contribute to our knowledge about teachers' learning in the context of PD and the development of teachers' learning through the prolonged interaction with a PD programme based on LS. In this way we aim to contribute to knowledge about teacher learning processes in a more general sense as well.

Literature Review

Teacher professional development

Borko et *al.* (2010) reviewed the literature on contemporary approaches to teacher PD and derived a number of essential characteristics of effective PD: (1) the content is situated in practice and addresses problems of practice; (2) the content is focused on students' learning; (3) preferred instructional practices are modelled; (4) PD fosters active teacher learning and teacher inquiry; (5) professional learning communities and collaborative learning environments are used; (6) PD settings are appropriate to goals, and are often school based; and (7) opportunities or models are on-going and sustainable. Similar features are mentioned by several other authors (e.g. Darling-Hammond & Richardson, 2009; Postholm, 2012; Van Driel, Meirink, Van Veen, & Zwart, 2012; Van Veen et *al.*, 2012). Desimone (2009) proposes a conceptual framework for studying the effects of PD on teachers and students. In the framework, core features of PD (such as content focus, active learning, coherence,

duration and collective participation) lead to increased teacher knowledge and skills, and change in teachers' attitudes and beliefs. These changes in teachers lead to changes in their instructional practices, which in turn lead to improved student learning. This all takes place in a context including teacher and student characteristics, curriculum, school leadership, and policy environment.

Webster-Wright (2009) argues that it is important to make a distinction between professional development and professional learning. She emphasizes the need to move beyond the current focus on how best to provide PD activities towards understanding more about the fundamental question of how professionals learn, a need that is prevalent not only in the teaching profession but in professional learning in general. We agree and make a distinction between teacher professional development and teacher learning, a distinction that often stays implicit in the literature. It parallels the distinction between learning and instruction, learning and teaching, and learning and learning environments. Teacher PD refers to a program, or a learning environment, which may have specific features. Examples of those features are those mentioned above in the reviews of Borko et *al.* (2010) and Desimone (2009). Teacher learning refers to *processes* and outcomes through which teachers increase or change their professional knowledge, understanding, skills, and attitudes.

In a recent review of the PD literature, Kennedy (2016) proposed that we need to base our conception of good PD more on a nuanced understanding of what teachers do, what motivates them and how they learn and grow, than on a collection of particular design features. She argues that our theories of student learning are better developed than our theories of teacher learning, an observation also made recently by Vermunt, Vrikki, Warwick and Mercer (2017). In Kennedy's view, many PD approaches are highly prescriptive which seems at odds with contemporary student learning theories emphasising the importance of metacognition and self-regulation. This view is endorsed by Noonan (2018). Based on his in-

depth study with teachers he developed the notion of powerful professional development. Essential for powerful PD in his view is the role of teachers' agency, autonomy and personalisation in making decisions about their own PD.

Lesson Study

A good example of a PD model is Lesson Study, which has rapidly gained popularity internationally during the last few decades (Lewis, Perry, & Murata, 2006). The core feature of Lesson Study is, according to Lewis et *al.* (2006), the "observation of live classroom lessons by a group of teachers who collect data on teaching and learning and collectively analyse it" (p. 3). The teachers aim to improve their lessons in some respect and plan a 'research lesson' together. One of them then teaches the lesson, while the others observe, make notes and collect data on the teaching and learning as it is happening. After the lesson, the teachers meet and analyse the data they have collected together (Lewis et *al.*, 2006). In its rapid spread around the world, Lesson Study has undergone some cultural adaptations in different countries. In their international review of the research literature on LS, Xu and Pedder (2015) were able to identify 67 studies that met their inclusion criteria. Of those studies, 34 were from North America, 23 from Asia, 8 from Europe and 2 from South Africa. Since the research reported in this paper was conducted in the UK, here we will focus on the model of Lesson Study that was used in this research, as developed and described by Dudley (2013, 2015). A main difference with the US implementation of LS is probably its larger focus on the learning of certain previously selected 'case pupils' in the planning, observation and analysis of research lessons.

Dudley's (2013, 2015) model of LS is depicted in Figure 1. In this model, the LS process typically consists of three cycles of Lesson Studies. The start of the process consists of an initial planning meeting of the LS group (typically consisting of 3-4 teachers) to determine what they want to improve and to identify (typically three) case pupils. After that,

the first LS cycle begins with the joint planning of the first research lesson. Subsequently, one of the teachers teaches the research lesson, while the other teachers observe in the classroom. Importantly, the observations are not so much focused on the teacher, but on the case pupils' learning as the lesson unfolds: how they learn, what difficulties they encounter, what understandings they develop, what misconceptions emerge as they articulate what they are learning. Soon after the lesson, the other teachers interview the case pupils to clarify aspects of the observations made, ask them what they enjoyed, and what they would do differently if the teacher was to teach the same lesson to another group. Then, the teachers meet formally again to discuss and interpret their observations and come to some conclusions for the next LS cycle. The second and third cycles follow the same format. At the end of the third cycle, the teachers are encouraged to share their overall findings, in writing or oral presentations, with their school or school district. The work is guided by a workbook, which asks teachers to explicitly state their lesson aims, their planned lesson activities, and success criteria for case pupils. It also asks them to record observations, evaluate the lesson, discuss the extent to which the success criteria were met for case pupils, and notice any surprises and findings from the lessons. In Japan it is not uncommon that the new knowledge is shared in a public research lesson, demonstrating innovations in teaching live in a class while dozens of teachers are observing; in the UK this has however not become widespread practice (yet). In addition to the LS cycles, sometimes seminars are provided in which subject matter, teaching and/or learning experts share their knowledge with the teachers. In this model of LS advocated by Dudley (2013; 2015) teachers' autonomy and agency play an important role (c.f. Kennedy, 2016; Noonan, 2018).

Insert Figure 1 about here

LS is attributed with creating the deep knowledge that Japanese teachers have of their curriculum subjects. It was cited by evaluators (Mourshed, Chijioke, & Barber, 2010) as a

key contributor to Japan's enduring high performance in TIMMS. Developed for use in the UK, its effects on improving mathematics at Key Stage 2[1] were evidenced by Hadfield, Jopling, and Emira (2011) and Dudley (2015), and it is being adopted by global educational high performers such as Singapore and Hong Kong. It seems to present many opportunities for professional collaboration within and between schools and institutes of higher education (Davies & Dunnill, 2008). Evidence from a UK LS project undertaken by the University of Exeter, working with over 100 school-based teachers, has identified several benefits afforded by LS, which include enhanced collaborative practice with colleagues and significant changes in teachers' professional practice and learning (Ylonen & Norwich, 2012).

In the review of Xu and Pedder (2015), the majority of studies (49 out of 67) aimed to determine the benefits and usefulness of LS in a particular local context. The majority of studies reported positive benefits related to teacher collaboration and the development of a professional learning community, the development of professional knowledge, practice and professionalism, more explicit focus on pupil learning, and improved quality of classroom teaching and learning. For example, a study by Lewis, Fischman, Riggs, and Wasserman (2013) in the US showed that teachers in LS teams expanded their mathematical content knowledge, became more skilful at eliciting and analysing student thinking, became more curious about mathematics and about student thinking, emphasized students' autonomous problem solving, and increasingly used multiple representations for solving mathematical problems. In a study involving Singaporean science teachers, Tan and Nashon (2013) found evidence of teacher learning through LS in increased degrees of student-centred pedagogy, increased awareness of the possibilities and limitations of their beliefs about science pedagogy, and the emergence of new understanding about new curricular content and science

[1] The National Curriculum in England 'is organised into blocks of years called 'Key Stages' (KS)' (Department for Education, 2013). Children's progress is assessed at the end of each KS. KS2 starts at Year 3 (7-8 years olds) and goes up to Year 6 (10-11 years olds), which is the end of primary education. KS3 starts at Year 7 (11-12 year olds), which is the first year of secondary education, and ends at Year 9 (13-14 year olds).

pedagogy. Disappointingly, only five of the studies in the Xu and Pedder (2015) review were focused on *how* teachers learn through LS. Xu and Pedder (2015) conclude that much more work needs to be done on describing and explaining how learning takes place in LS processes (see also for example Lewis et *al.* (2006), and Tepylo and Moss (2011)).

Processes and patterns of teacher learning

Beijaard, Korthagen, and Verloop (2007) consider the question of how teachers learn to be of utmost importance, since such knowledge may lead to improvements of both initial teacher education and further PD of teachers. Teacher learning is conceptualised in different ways in the literature. Here, we build on Vermunt and Endedijk (2011) and conceptualise teacher learning as a process in which teachers attain learning outcomes (changes in knowledge, beliefs, skills, attitudes) through the use of cognitive, affective, regulative and social learning activities. This process is influenced both by contextual factors (for example PD, school culture) as well as personal factors (for example, motivation, beliefs about learning, teaching experience, professional identity, and agency) (e.g. Leeferink, Koopman, Beijaard, & Ketelaar, 2015).

In earlier conceptualisations of teacher learning the emphasis was on overt and observable learning activities, such as 'reading', 'participating in workshops', 'discussing', etc. (e.g. Kwakman, 2003). Tynjälä (2008), in a review of research on workplace learning in a variety of professions, summarised the answers provided by some recent studies to the question of how people learn at work as follows: by doing the job itself; through co-operating and interacting with colleagues; through working with clients; by tackling challenging and new tasks; by reflecting on and evaluating one's work experiences; through formal education; and through knowledge gained from contexts outside work.

In recent conceptualisations of teacher learning, more attention has been given to covert or mental learning activities. Many authors have emphasized the importance of reflection in

teacher learning (e.g. Korthagen, 2010; 2017; Schön, 1984). For example, Korthagen's (2017) cyclical ALACT model, building on experiential learning theories like Kolb's (1984), discerns five phases: (1) action; (2) looking back on the action; (3) becoming aware of essential aspects; (4) creating alternative methods of action; and (5) trying out new actions, after which a new cycle begins. All these thinking activities together are subsumed under the general term 'reflection'.

In the context of a large-scale research and development project on learning to learn in classrooms, schools, and networks James and McCormick (2009) found four dimensions of teacher learning: inquiry, building social capital, critical and responsive learning, and valuing learning. They conclude that although teachers appreciate practical advice, classroom practices can become ritualised and mechanistic when teachers are not stimulated to think about the principles of learning that underpin them. Other important teacher learning activities mentioned in the literature are, for example, analysing videotaped classroom events (Seidel, Stürmer, Blomberg, Kobarg, & Schwindt, 2011), sharing knowledge and opinions, exploring new ideas and reflecting on practice in an online social networking site (Kamalodeen, 2014) and collectively looking at students' work (Little, Gearhart, Curry, & Kafka, 2003). Pyhältö, Pietarinen, and Soini (2015) point to the role of teachers' professional agency in their learning and contribution to school development.

As mentioned above, learning patterns are viewed here as a coherent whole of learning activities that learners usually employ, their beliefs about learning and their learning motivation, a whole that is characteristic of them in a certain period of time. Bakkenes, Vermunt, and Wubbels (2010, p. 536) describe teacher learning as an active process "in which teachers engage in activities that lead to a change in knowledge and beliefs (cognition) and/or teaching practices (behaviour)". They studied teachers' learning in the context of the introduction of a large-scale national educational innovation aimed at increasing students'

active and self-regulated learning in upper secondary education. Ninety-four teachers were followed for a year and asked to report on their learning experiences in digital logs, six times during the year. The researchers content-analysed the logs for evidence of teacher learning. They found that most teachers' learning was focused heavily on *applying* what they had learned to improve their immediate teaching in the classroom. These teachers wanted to apply new ideas in their teaching and experimented with new practices, but stayed within the boundaries of their existing theory of practice (application-oriented learning pattern). Other teachers were (also) *meaning-oriented* in their learning: these teachers wanted to know *why* things worked as they worked in the classroom, looked for reasons behind new practices, tried to extend their understanding of their own practices and of new ideas, tried out new practices based on that understanding, worked on extending their theory of practice, often brought in knowledge and theory from outside and worked for a longer time on a certain theme (meaning-oriented learning pattern). A third, but substantial, group could be characterised as *problematic* in their learning. These teachers struggled with the educational innovation, experienced many frictions between how they wanted to teach and how that worked out in practice, often had no idea how to teach in another way, did not know how they might learn to teach in another way, had many negative emotions and sometimes avoided learning about the innovation at all (problematic learning pattern). At this point it is useful to note that these problematic learning experiences are not undesirable in themselves. On the contrary, they may be indicating that teachers are actually attempting change and challenging their existing beliefs but are still struggling with developing productive new views and teaching practices. In a case study with two teachers in the context of a PD programme, Van den Bergh, Ros, and Beijaard (2016) found that the two teachers differed greatly from each other in their learning. One teacher showed a meaning-directed learning pattern, while the other teacher's learning pattern was problematic in nature.

Bakkenes et *al.* (2010) did not find a dimension often identified in research on *student* learning, namely a reproduction-oriented learning pattern, among their experienced teachers. It seems likely that this way of learning, aimed at being able to reproduce knowledge on a test, is not particularly appropriate to a professional learning context and hence teachers do not adopt such an approach in their own learning (although they may stimulate it in their students). However, in studies on student teachers' learning patterns in initial teacher education this pattern is sometimes found (e.g. Ahonen, Pyhälto, Pietarinen, & Soini, 2015; Donche & Van Petegem, 2009; Endedijk, Donche, & Oosterheert, 2014). For example, Ahonen et *al.* (2015) found a learning pattern that can be characterized as reproduction-oriented. These student teachers' main goal was to get an academic qualification; they showed little or no interest in teaching and they often took a surface approach to learning.

Learning patterns are not viewed here as mutually exclusive dimensions. Particular teachers may exhibit features of different learning patterns. Some teachers may exhibit all features of one particular pattern, while others may be more versatile and show characteristics of two or even more patterns.

Evidence on the role of teaching experience in the development of teachers' learning patterns is inconclusive. For example, Leeferink et *al.* (2015) showed how teachers' work experiences were transformed into learning experiences, while Oosterheert, Vermunt, and Veenstra (2002) found only weak relationships between teaching experience and learning patterns.

The Camden Lesson Study project

Overall project

The project 'Establishing a self-renewing population of high order mathematics teachers through training and Lesson Study' ran for two school years and could be characterised as a development and research project. The project's aim was to "transform

standards of mathematics teaching across Key Stage 2 and Key Stage 3, securing the highest outcomes for pupils within the new National Curriculum by creating a self-sustaining Lesson Study community of teachers and Lead Practitioners and a network of schools delivering joint professional learning supported by excellent resources" (Lang, 2013). Among the more specific aims were improving the mathematical subject and pedagogical knowledge of primary and secondary teachers and their precision knowledge of how to teach difficult aspects of mathematics from year 5 to year 8. The LS approach adopted in this project followed Dudley's (2013, 2015) model as described above.

Research project

The main aims of the research project within the overall project were: (1) to identify the powerful and less powerful components of teacher discussions as part of an intervention model that can support and foster teacher learning; (2) to understand the influence of Lesson Study on teacher learning; and (3) to contribute to theory development about understanding and improving teacher learning in the context of educational innovation.

Data derive from the overall project described above. With the new mathematics curriculum in place, this large-scale project aimed to incorporate LS into teachers' practice in 59 primary, secondary and special schools across London. Some schools entered in the first year of the overall project (cohort 1), most of whom continued on to the second year; others joined in the second year (cohort 2). Teachers in each school were involved in iterative LS cycles (a cycle of three research lessons per term). Their LS meetings were video-recorded and subsequently analysed for evidence of teacher learning. Results of these video analyses have been reported in Vrikki, Warwick, Vermunt, Mercer, and Van Halem (2017). A second research strand focused on the learning patterns and perceptions of LS of a representative sample of teacher learners from the programme. In this paper, results of the second study will be reported.

Research question and hypotheses

The central research question of the study was: What is the influence of Lesson Study on the learning patterns of mathematics teachers in the context of the introduction of the new National Curriculum?

The following hypotheses were tested:

1a. Teachers' learning patterns (i.e. levels of meaning-oriented learning, application-oriented learning, and problematic learning) improve in quality when teachers participate in LS.

1b. Teachers' perceptions of the value of LS, with respect to learning outcomes and professional development, are positively related to the increase of quality of teacher learning in the context of LS.

1c. The development of learning patterns differs across teachers with different levels of teaching experience.

2a. Teachers from schools with one year of LS experience show higher quality of teacher learning than teachers from schools with no LS experience.

2b. Differences in the quality of teacher learning based on LS experience persist when controlling for the way teachers perceive the value of LS for promoting their learning outcomes and professional development.

With 'high quality' of teacher learning we mean high(er) levels of meaning-oriented and application-oriented learning and low(er) levels of problematic learning.

Method

Participants

Teachers who participated in the study were in-service mathematics teachers and consisted of two cohorts: teachers from schools who already had one year's experience of LS at the time the first inventory was administered (cohort 1); and teachers from a second cohort

of schools who had no Lesson Study experience yet at that time (cohort 2). The teachers for the study were recruited from all teachers who participated in the LS project. The figures on the sample of this study are presented in Table 1.

Insert Table 1 about here

Sixty-five teachers completed both inventory 1 and 2 (11 from the first cohort schools 54 from the second cohort schools) and 39 teachers completed inventory 1, 2, and 3. Teachers were asked to report their age (in inventory 1, 2, and 3), teaching experience (inventory 3), and gender (inventory 3). The average age of the teachers was 35.81 years (*SD* =9.57; *N* = 172); the average amount of teacher experience was 9.49 years (*SD* =7.23; *N* = 73); 29.58% of the participants were male and 70.42% of the participants were female (*N* = 71).

Design

Three methodological strategies were used, applying methodological triangulation (Cohen, Manion, & Morrison, 2000). First, the development of teachers' learning patterns over the course of a year in which teachers participated in LS was modelled; testing hypothesis 1a-c. Teachers from cohort 1 were excluded from this analysis, due to an insufficient sample size (*N* = 7) and because they already had LS experience before the first study was conducted. Teachers from cohort 2 had no LS experience at the time inventory 1 was administered (time 1), and they participated in LS between inventories 1 and 2, and between inventories 2 and 3 (time 2 and 3). Along with the development of the teachers' learning patterns, the development of their perceptions of LS over time was noted and the influence of teaching experience was explored. This was achieved by testing whether the development of learning patterns differed between teachers with different levels of teaching experience.

Secondly, teachers from schools with and without LS experience were compared at time 1 (i.e. teachers from cohort 1 vs. teachers from cohort 2 in inventory 1), testing

hypothesis 2a. Here we tested whether or not teachers' perceptions of LS influenced the quality of teacher learning across the groups, testing hypothesis 2b.

Materials

Inventory 1 consisted of two parts: Teacher Learning and Perceptions of Lesson Study. The *Inventory of Teacher Learning* section contained 45 statements about teachers' learning in the context of their profession. The items were derived from a model of teacher professional learning (Vermunt & Endedijk, 2011) and qualitative quotes from the Bakkenes et *al.* (2010) empirical study about teacher learning (see Literature review). Teachers were asked to indicate the extent to which each statement matched their own professional learning as a teacher on a 5-point Likert scale, varying from (1) strongly disagree to (5) strongly agree. Three teacher learning patterns were operationalized in the items: meaning-oriented learning, application-oriented learning, and problematic learning. Examples of items measuring meaning-oriented learning were: 'I analyse why my pupils don't understand something'; 'I try to understand why certain teaching methods work'; 'I learn from comparing different students' work'; 'I think about how different lessons relate to each other'; and 'I try to understand how students learn'. Items measuring application-oriented learning included: 'I want to apply new ideas in my teaching'; 'I learn most from my own practical experiences'; I like to get practical hints and tips on how to improve my teaching practice'; 'I want to know which teaching methods work'; and 'I learn best when I try out new ideas in practice'. Items measuring problematic learning were, for example: 'I don't know how to teach mathematics in another way than I'm used to'; 'I have a growing feeling of discontent with my teaching'; 'I struggle with new ways of teaching'; 'I view lessons as separate entities'; and 'I only want to learn things that I can use immediately in my teaching'.

The *Perceptions of Lesson Study* section contained 20 statements about teachers' perceptions or expectations about LS. Teachers from schools new to LS were asked about

their expectations, the others about their experiences. Items referred to various potential learning outcomes as a result of participation in LS, and to the value of LS as a model of professional development. Teachers were asked to indicate their level of agreement with the statements on a 5-point Likert scale, varying from (1) strongly disagree to (5) strongly agree. Items in the scale 'learning outcomes' were, for example: 'I have learned new teaching approaches for the future' and 'I have improved my understanding of my students' abilities'. Items measuring 'professional development' were for example: 'Lesson study is an effective model of professional development for me' and 'I have reduced feelings of professional isolation'.

Inventory 2 and 3 contained the same two sections as Inventory 1. However, as a result of factor and reliability analyses on the data of Inventory 1, the number of items in both parts of the inventory was reduced. The *Inventory of Teacher Learning* section in Inventory 2 and 3 consisted of 32 items and the *Perceptions of Lesson Study* section of 14 items. All analyses on the data of inventories 1, 2 and 3 were done with these 46 items. Moreover, since at the time of administration of Inventory 2 all participating teachers had experience with LS, the Perceptions of LS part had only one version: all teachers were asked about their experiences, and not about their expectations of LS.

Procedure

The study consisted of three waves of inventory administrations during one school year, the second year of the LS project. Inventory 1 was administered during planning conferences for the participating teachers by the end of September. Inventory 2 was administered during feedback conferences for the participating teachers in the middle of March. Inventory 3 was administered during feedback conferences in the beginning of July. In all cases, participating teachers who were not present during these conferences were emailed with the request to complete an online version of the inventory.

Analysis

All data analyses were conducted using the Statistical Package for the Social Sciences (versions 22.0 and 24.0, SPSS Inc., Chicago, IL, USA).

Development of teacher learning patterns in the context of Lesson Study. The effect of LS on quality of teacher learning over time (looking at cohort 2 and using three measurements; Hypothesis 1a), was investigated with a Repeated Measures (RM) Analysis of Variance (ANOVA) for each dependent variable separately (i.e. meaning-oriented learning, application-oriented learning, and problematic learning). In order to examine an interaction effect between quality of teacher learning and development over time, a two-way RM ANOVA design was adopted (N = 32, only cohort 2 teachers) and the Greenhouse Geisser post hoc test was used for examination of effects (Field, 2013). Time was added to the models as a three-level factor and, in the two-way RM ANOVA, the dependent variables were added together in a three-level factor called 'teacher learning', which enabled us to test a possible interaction effect. Profile plots were obtained in order to examine interactions between time and the dependent variables.

Accordingly, we obtained a profile plot of LS perceptions, in order to investigate whether these variables appeared stable over time. When this was the case, it would be possible to interpret these variables as a covariate in the RM ANOVA model (Hyothesis 1b). Finally, we obtained profile plots for the development of learning patterns over time across different levels of teaching experience (hypothesis 1c). In the literature, different grouping criteria for teaching experience are described. In a widely cited paper Hargreaves (2005) used three cut-off scores to refer to career stages: less than five years of teaching experience, between 5 and 10 years, between 10 and 15 years, and over 15 years. He considers teachers with less than 10 years of experience as generally still in an early stage of their career, which has an effect on the way they respond to new initiatives. Ingraham (2003) used a similar cut-

off point of 10 years to distinguish between early career teachers and experienced teachers. Following Hargraves (2005) and Ingraham (2003) and given the limited sample size (i.e. N = 32), we divided teaching experience in two levels: 0-9 years of experience (N = 25 in cohort 2, N = 21 in the analysis) and 10-28 years of experience (N = 22 in cohort 2, N = 11 in the analysis). Assumptions of normality, linearity, and homogeneity of variance were met. The assumption of sphericity was not met in the two-way RM ANOVA model; therefore a Greenhouse Geisser adjustment was made. We controlled for missing data (items on scales) with multiple imputation methods.

Teacher learning patterns and teacher LS experience. In order to examine how teachers from schools with and without LS experience differ in quality of teacher learning (dependent variables: meaning-oriented learning, application-oriented learning, and problematic learning) (testing Hypothesis 2a), and to examine whether or not perceptions of LS influence this relation (testing Hypothesis 2b), a MANCOVA (N = 161; N = 27 in cohort 1; N = 134 in cohort 2) was performed. A planned comparison was conducted, since it was expected that LS experience led to higher quality of teacher learning. By doing so, post-hoc tests (and following biases due to multiple testing) were avoided. The analysis consisted of the following steps. Firstly, a MANOVA model with dependent variables only was tested, and accordingly the intended MANCOVA was run with the covariates. This way, we checked whether effects would change by adding the covariates to the model. Non-significant effects of covariates were deleted from the model and the final model was tested. Assumptions of normality, linearity, and homogeneity of variance were met. We controlled for missing data (items on scales) with multiple imputation methods. Furthermore, the biases found in the distributions, means, standard deviations, and standard errors of the included variables were controlled using a simple bootstrapping method (k = 1000); no substantial biases were found.

The group sizes were unfortunately not equal, which will be considered when interpreting the results.

Results

Reliabilities and loadings of the scales

Cronbach alpha values were computed for all scales entered in the analyses. These varied over the three administrations for the three teacher learning pattern scales between .83 and .91 for the scale meaning-oriented learning (N items = 14), between .77 and .87 for the scale application-oriented learning (N items = 9), and between .76 and .80 for the scale problematic learning (N items = 9). For the two LS perception scales the Cronbach αs varied between .86 and .88 for the learning outcomes scale (N items = 9) and between .73 and .80 for the professional development scale (N items = 5). Table 2 shows the factor loadings of typical Teacher Learning items in a three-factor Varimax solution, Table 3 shows the factor loadings of typical Perceptions on Lesson Study items in a two-factor Varimax solution.

Insert Tables 2 and 3 about here

Development of teacher learning patterns in the context of Lesson Study

We tested whether the quality of teacher learning improved over time. In line with our hypothesis, the one-way RM ANOVAs showed a positive linear main effect of time on meaning-oriented learning and a negative linear main effect of time on problematic learning. However, there was no main effect of time on application-oriented learning. In Table 4 the descriptive statistics and test statistics are provided for the significant predictors.

Insert Table 4 about here

Measures of effects (*p* values and partial eta square) indicate a large effect of time (spend in the context of LS) on meaning-oriented learning (it increases) and problematic learning (it decreases). The two-way RM ANOVA showed a significant linear interaction

effect between time and teacher learning ($F_{(4, 28)} = 16.89$; $p < .001$; partial $\eta^2 = .71$). The main effect of time on the teachers' learning patterns is depicted in Figure 2.

Insert Figure 2 about here

In order to examine whether we could test Hypothesis 1b, a profile plot was obtained of the development of teachers' perceptions of LS with respect to learning outcomes and PD over the three inventory administrations. As shown in Figure 3, there is a quadratic effect of time on perceptions of LS. Given this development, it was not possible to test whether teachers' perceptions of LS influence the development of quality of their learning over time.

Insert Figure 3 about here

In order to test Hypothesis 1c, three profile plots were obtained, in which the developments of the three teacher learning patterns across levels of teaching experience are represented. In Figure 4, the above described change in meaning-oriented learning patterns between teachers with different levels of teaching experience is shown. The difference between time 1 and time 2 for the two groups is striking. Teachers with ten years of experience or more show little or no development and teachers with less than ten years of experience show a steep increase in meaning-oriented learning. However, the two groups meet each other on the same level at the time of the second inventory. From inventory 2 onwards, the increase in meaning-oriented learning patterns remains approximately equal for both groups.

Insert Figure 4 about here

No substantial differences showed up between teachers with more than ten years and those with less than ten years of teaching experience, with regard to the change in application-oriented and problematic learning patterns. It can be concluded that there are differences in changes to teacher learning patterns over time, between teachers with different

levels of teaching experience during LS participation; however, this only applies for the change in meaning-oriented learning.

Teacher learning patterns and teacher experience with Lesson Study

We tested whether teachers from schools with LS experience showed higher quality of teacher learning than teachers from schools without LS experience at time 1. In the first model, significant multivariate main effects were found for the teachers' cohorts on quality of teacher learning. Teachers from cohort 1 reported significantly more meaning- and application-oriented learning and less problematic learning than teachers from cohort 2 (See Table 5). Overall, small to medium effects sizes were found for LS experience on quality of teacher learning (Table 6). However, it is known that unequal group sizes tend to have an influence on partial eta square statistics and therefore these should be interpreted with caution (Cohen, 1973).

The second model showed that the variable perceptions of LS with respect to learning outcomes was overall a significant covariate, as well as the variable perceptions of LS with respect to PD (Table 6). The multivariate main effects of LS experience on quality of teacher learning remained when controlling for how teachers perceived the value of LS for promoting their learning outcomes and professional development. Therefore, Hypotheses 2a and 2b are supported.

Yet, looking at the different dependent variables, it appeared that perceptions of LS with respect to professional development did not influence the relation between LS experience and application-oriented learning. Furthermore, perceptions of LS with respect to both learning outcomes and professional development did not influence the relation between LS and problematic learning. In Table 5, an overview of all significant parameters is provided.

Insert Table 5 about here

The coefficients show that when the perceived value of LS is high, teachers tend to show more meaning-oriented and application-oriented learning, and less problematic learning.

In Table 6, the descriptive statistics of the dependent variables are provided, as well as the model fit and effect sizes. It appears that quality of teacher learning is indeed higher for teachers from schools with one year of LS experience, compared to teachers from schools without LS experience. The model fit is substantial, but effect sizes are small (Cohen, 1973).

Insert Table 6 about here

Conclusions

Our main Hypothesis (1a) was confirmed. Teacher learning patterns did indeed become higher in quality when participating in LS. Meaning-oriented learning increased and problematic learning decreased during the year that teachers were engaged in Lesson Study professional development. Both effects are large. The level of application-oriented learning did not change significantly over time for the whole group - it was high in the beginning and stayed high throughout the research year. Hypothesis (1b) was that 'High perceptions of the value of LS with respect to learning outcomes and professional development are positively related to the increase of quality of teacher learning in the context of LS'. Testing this hypothesis was not possible, because of the quadratic effect of time on perceptions of LS. At the start of the LS program the perceived value of LS both with respect to learning outcomes and professional development were high, then they both decreased, and towards the end of the programme both increased again.

There were differences in changes in teaching learning patterns during participation in LS between teachers with different levels of teaching experience, but these differences only pertained to meaning-oriented learning. Thus, Hypothesis (1c) was partly confirmed. Teachers with less than ten years of teaching experience showed a sharp increase in meaning-

oriented learning during the first half year of LS, while for teachers with ten or more years of teaching experience meaning-oriented learning did not change during the first half year. After that time both groups' levels of meaning-oriented learning were roughly equal. During the second half year of LS there was an equal increase in meaning-oriented learning for both groups. With regard to the development of application-oriented and problematic learning, no significant differences were revealed between teachers with different levels of teaching experience.

Hypothesis (2a) predicted that 'Teachers from schools with one year of LS experience would show higher quality of teacher learning than teachers from schools with no LS experience'. This hypothesis was supported. Teachers from schools with one year of LS experience showed significantly more meaning-oriented and application-oriented learning and less problematic learning than teachers from schools with no LS experience. The effect sizes are small to medium. Hypothesis (2b) was also confirmed. The effects of LS experience on the quality of teacher learning remained when controlling for teachers' perceptions of the value of LS with respect to learning outcomes and professional development. In other words, the results suggest that the effect of LS experience on the quality of teacher learning seems independent of the value teachers attach to LS. Moreover, the perceived value of LS showed independent additional effects on the quality of teacher learning. When the perceived value of LS was high, teachers tended to show more meaning- and application-oriented learning.

Discussion

In the following discussion we will seek possible explanations for the observed findings, relating them to the literature and theoretical framework discussed in the beginning of this paper. Although we explore alternative explanations, we cannot be sure at this stage which of these are most likely to apply. Although an important outcome of the study is the identification and description of different kinds of teacher learning, we believe our data is

also revelatory in other ways. Because of its longitudinal nature, with repeated measurements made, the study in our view describes development in teacher learning as well.

Our finding that the Lesson Study approach to professional development fosters meaning-oriented teacher learning may, first of all, be explained by the strong focus that LS places on analysing and understanding case pupils' learning. Moreover, especially in the reflective LS sessions, teachers try to find explanations for students' misunderstandings and try to relate those misunderstandings to how mathematics has been taught in the target lessons (Bocala, 2015). Teachers choose themselves what they aim to improve in their lessons, which gives them a significant amount of agency and ownership of their learning. This resonates well with the importance attached to autonomy, agency and personalisation in teacher learning emphasised by researchers such as Kennedy (2016) and Noonan (2018). From other research, we know that meaning-oriented learning and self-regulation are closely intertwined (Fryer & Gijbels, 2017; Pyhältö et *al.*, 2015). The core of meaning-oriented learning is the integration of different knowledge sources (e.g. experiential, theoretical, and practical) into an integrated theory of practice (Vermunt et *al.*, 2017). Lesson study is focused on subject knowledge, teaching and pupils' learning, and on the integration of these core elements to improve the quality of teaching. Horn and Kane (2015) found similar results in a study of mathematics teacher workgroups. Their study indicated that as groups progressed, they showed an increasing integration of talk about teaching, students and mathematics. Finally, LS fosters research-based, observation-based reflection, diagnosis and analysis of student subject matter learning; and this type of teacher PD is well aligned with meaning-oriented teacher learning (Korthagen, 2017).

The results of our study show that problematic learning decreases when teachers are engaged in LS professional development. As noted in the literature review, becoming aware of problems when learning about an innovation may be a helpful stage in realizing that one's

current way of teaching no longer suffices and thus increasing willingness to try out new approaches. LS puts a high emphasis on collaborative learning, lesson preparation and reflection on lessons. If teachers experience problems with new teaching and learning methods, these collaborative workgroups may well structure teachers' learning and alleviate problems with teaching and learning. Moreover, the fact that teachers observe each other's practices in research lessons, and perceive the impact of these practices on pupils' learning, may give struggling teachers the feeling that change is actually and practically possible (Zwart, Wubbels, Bergen, & Bolhuis, 2007). The joint planning, analysis and reflection of research lessons may help teachers to internalize those planning, analysis and reflection activities and thus reduce their problematic learning (Bakkenes et *al.*, 2010).

With regard to application-oriented learning, our study found that this was high from the beginning and did not increase over time; but teachers from schools with LS experience engaged in more application-oriented learning than teachers from schools new to LS. One explanation for this difference could be statistical: that the power for the Multivariate (cross-sectional) ANOVA was sufficient to detect a change (N=161), but that the power of the Repeated Measures (longitudinal) ANOVA analysis was not sufficient to detect a change (for this analysis N = 32). Another explanation could be that application-oriented learning was already high at the start and that therefore there was not much scope for increase.

From other research, we know that application-oriented learning is, in general, the favoured way of learning for many teachers and, indeed, professionals in general (Tynjälä, 2008; Bakkenes et *al.*, 2010). Our findings support this, as can be seen in the highest mean scores on application-oriented learning compared to the other two learning pattern scales on all measurement moments. The results even show a slight upward trend in mean scores for application-oriented learning in the longitudinal study as well, although this rise was not statistically significant. Of course, the most salient characteristic of Lesson Study that may

encourage this kind of learning is that it addresses problems of practice. Moreover, there is a high focus on what case students learn (cf. Little et *al.*, 2003). LS is aimed at improving teaching practices and on learning from one's own practical experiences.

Overall, then, the outcomes of this study suggest that LS has a beneficial impact on the quality of teacher learning. The results from the longitudinal and cross-sectional study provide converging evidence. First, the cross-sectional study showed that teachers from schools who had been working with LS for a year, reported more meaning-oriented and application-oriented learning, and less problematic learning, than teachers from schools with no LS experience yet. Second, the longitudinal study confirmed most of these conclusions and showed that LS has a positive impact on the quality of teacher learning, with a significant increase of meaning-oriented learning and decrease of problematic learning as LS progressed (compare Bocala, 2015).

A remarkable finding of the study was that initially the perceived value of LS by teachers was high, then it decreased, and towards the end of the programme the perceived value increased again. When teachers start with Lesson Study, their expectations about the value of LS are high. The initial experiences inevitably introduce practical and intellectual problems that mitigate expectations, although overall LS is still highly valued. After prolonged exposure to LS, however, the perceived value increases completely (with respect to professional development) or almost completely (with respect to learning outcomes) to the level of initial expectations. These somewhat surprising results may be related to the time it takes to attain these kinds of outcomes. One of the identified characteristics of effective professional development is that it is of sufficient duration to have a meaningful impact (Borko et *al.*, 2010).

The results showed some differences between experienced and less experienced teachers in their development of learning patterns, but only for meaning-oriented learning.

The effects of LS on meaning-oriented learning were initially larger for teachers with less teaching experience than for teachers with a lot of teaching experience. These initial differences disappeared after only half a year of Lesson Study. Perhaps the highly collaborative nature of LS helps to achieve this effect (Ylonen & Norwich, 2012). Teachers learn from each other, and it is well possible that initially less experienced teachers learn more from experienced teachers than the other way around. It could also be that more experienced teachers are more resistant to change in general because they are more 'used to' a certain way of working/thinking than less experienced teachers. However, after half a year of LS the less experienced teachers have 'caught up' in their level of meaning-oriented learning and from that moment on the benefits of the collaboration are more reciprocal.

Interestingly, most effects of LS in this study were on teachers' adoption of meaning-oriented learning. Thus, LS seems to be a form of PD with the power to foster this kind of learning. Characteristics of Lesson Study that may particularly explain this beneficial effect are its strong focus on both students' learning (Little et *al.*, 2003) and teachers' ownership of what they want to improve in their teaching (Kennedy, 2016; Noonan, 2018; Pyhältö et al., 2015). The active, inquiry-based nature of LS may also be an important factor (Korthagen, 2017). Moreover, LS seems to stimulate teachers to use cognitive and metacognitive learning activities like analysis, diagnosis, explanation, hypothesis formation and testing, causal reasoning, planning, reflection. They are encouraged to compare predictions about case pupils with observations, and compare v of different case pupils (Mansvelder-Longayroux, Beijaard, & Verloop, 2007). Teachers value LS because of the focus on subject matter, teaching, and pupils, which are the three core elements of teachers' professional identity (Beijaard, Meijer, & Verloop, 2004; Horn & Kane, 2015; Noonan, 2018). Lesson Study is aimed both at gaining understanding about how teaching particular subject matter impacts on student learning, as well as at improving practice. Through the collaborative nature of LS,

teachers can learn from each other, observe and discuss one another's practices, and give and receive feedback on those practices (Zwart et *al.*, 2007). Finally, the relatively long duration of LS provides the time needed to foster meaning-oriented learning (Asikainen & Gijbels, 2017). Other models of PD than LS which show similar characteristics may work through similar mechanisms, by improving the quality of professional learning processes and patterns (Kennedy, 2016).

The study reported in this paper has, of course, its limitations. It was conducted in a naturalistic setting which made it unfeasible to apply an experimental design with a control group. The sample size of the group that completed all three inventories was relatively small so some effects of LS may be masked. The data are based on self-reported inventories. Although self-reports have their limitations, the shift toward meaning-oriented learning observed in this study is in our view not an artefact of the different inventories used over time. First, there was no shift toward application-oriented learning over time and the shift in problematic learning was in the opposite direction. Second, teachers were quite frank in voicing their criticism of LS in the second wave of data collection, so they did not seem particularly inclined to please the researchers. As discussed in the Introduction, the whole research project had two research strands: a series of smaller-scale analyses of video-taped teacher discussions in pre- and post-research lesson meetings part of Lesson Study, and a larger-scale, program duration inventory study in which many teachers were asked about their learning experiences in the Lesson Study project. Both types of evidence have their strengths and weaknesses and they can be combined and triangulated to increase our understanding of teacher learning in Lesson Study.

Future research should, we suggest maintain a focus on both teacher and student learning. Moreover, it may be interesting to include different models of LS as they are emerging in different countries. For example, some forms of LS are currently implemented in

which professional coaches are added to the LS groups (e.g. Van Halem, Goei, & Akkerman, 2016). We need to know what the impact of such changes is on, for example, the experienced ownership and agency of the teachers in LS groups. As Xu and Pedder (2015) argue, more research on the processes of teacher learning should be conducted. The current study has shed light on some of the possible explanatory mechanisms intervening between LS as a PD model and teacher learning outcomes, but more research is needed. How the quality of dialogue within LS groups relates to teacher learning is certainly another area worthy of further investigation (e.g. Littleton & Mercer, 2013; Vrikki et *al*., 2017).

Since much research in this field is rather small-scale research, future large-scale experimental research is urgently needed. The collection of behavioural data from both students and teachers should be incorporated in these designs as well (Alexander, 2017). Much of the research on LS has been focused on the teaching and learning of mathematics. Future research should focus on the value of LS in other subject domains and whether adaptations should be made to suit those domains. Likewise, as much of the research is focused on primary and secondary education, research is needed that focuses on other sectors like higher education (Soto Gómez, Serván Núñez, & Pérez Gómez, 2015).

In using the model of LS in new circumstances and cultures, adaptations have to be made to provide an optimal fit to those new environments. For example, Vrikki et *al.* (2017) showed that teachers in the UK exhibit certain dialogic features that contribute to productive discussions. However, at least some of those characteristics may be culture-specific and relate to the norms of 'politeness' of discussions in the UK, which may not apply to teachers' discussions in other cultural settings. Cultural adaptation of LS might also be needed if it were used to improve teaching and learning in higher education, where concepts such as 'classroom' and 'lesson' may not be relevant.

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Table 1

Number of teachers participating in the three inventory administrations

	N Inventory 1 (response rate)	*N* Inventory 2 (response rate)	*N* Inventory 3 (response rate)	*N* participating teachers in total
Cohort 1	27 (54%)	22 (44%)	26 (31%)	58
Cohort 2	134 (95%)	80 (57%)	47 (35%)	156
Total	161	102	73	214

Table 2

Factor loadings of typical Teacher Learning items in a three-factor Varimax solution

(Principal Component analysis; loadings < .30 omitted; study 1; N=161)

Factor loadings			Items and scales
F1	F2	F3	
			Scale meaning-oriented learning (N=14)
.66			I analyse why my pupils don't understand something
.55			I think about how different lessons relate to each other.
.51			I try to understand why certain teaching methods work.
.49		.42	I try to understand how students learn.
			Scale problematic learning (N=9)
	.70		I only want to learn things that I can use immediately in my teaching
-.32	.68		I don't know how to teach mathematics in another way than I'm used to
-.33	.52		I have a growing feeling of discontent with my teaching
	.52		I view lessons as separate entities
			Scale application-oriented learning (N=9)
		.68	I want to apply new ideas in my teaching
		.56	I learn most from my own practical experiences
		.56	I like to get practical hints and tips on how to improve my teaching practice
		.53	I want to know which teaching methods work

Table 3.

Factor loadings of typical Perceptions on Lesson Study items in a two-factor Varimax solution (Principal Component analysis; loadings < .30 omitted; study 1; N=161)

Factor loadings		Scales and items
F1	F2	
		Scale learning outcomes (N=9)
.78		I have learned new teaching approaches for the future
.75		I can prepare lessons which are more suitable for my students
.59		I have improved my understanding of my students' abilities
.55		I have increased my mathematical knowledge
		Scale professional development (N=5)
	.75	I have created a strong sense of teacher community
	.74	Lesson Study is an effective model of professional development for me
	.74	I have reduced feelings of professional isolation
	.71	I have improved my collaboration with my colleagues

Table 4

Development of teacher learning patterns over a school year in the context of Lesson Study: Descriptive statistics and main effects.

Main effects	T1 *M (SD)*	T2 *M (SD)*	T3 *M (SD)*	*F* (df)	*p*	partial η^2
Meaning-oriented learning	3.94 (.29)	4.08 (.33)	4.23 (.35)	14.22 (2, 30)	.00	.49
Problematic learning	2.37 (.50)	2.26 (.53)	2.02 (.46)	15.02 (2, 30)	.00	.50

Abbreviations: df = degrees of freedom; M (SD) = mean (standard deviation); T = Time point.

Note: Alpha = .05

Note: Time points correspond to the times that inventories 1, 2 and 3 were administered.

Table 5

Teacher learning patterns and teacher experience with Lesson Study: Parameter estimates

Dependent Variables	Parameters	*B (SE)*	*p*	95% *CI*		*Partial* η^2
				LB	UB	
Meaning-oriented Learning	Intercept	2.93 (.27)	.00	2.40	3.45	.44
	Learning Outcomes	.14 (.07)	.04	.01	.28	.03
	Professional Development	.12 (.05)	.02	.02	.22	.04
	LS Experience	.24 (.08)	.00	.09	.38	.06
Application-oriented Learning	Intercept	2.76 (.24)	.00	2.29	3.23	.47
	Learning Outcomes	.31 (.06)	.00	.19	.43	.14
	LS Experience	.24 (.07)	.00	.11	.37	.08
Problematic Learning	Intercept	2.66 (.41)	.00	1.85	3.48	.21
	LS Experience	-.36 (.12)	.00	-.59	-.13	.06

Abbreviations: B (SE) = coefficient (standard error); CI = confidence interval; LB = lower bound; UB = upper bound.

Note: Alpha = .05

Table 6

Teacher learning patterns and teacher experience with Lesson Study: Descriptive statistics, main effects and model fit.

			Model 1		Model 2	
Main effects	*M (SD)* cohort 1	*M (SD)* cohort 2	*F* (df)	*p*	*F* (df)	*p*
Meaning-oriented learning	4.26 (.35)	4.02 (0.36)	10.44 (1, 159)	.00	9.92 (1, 156)	.00
Application-oriented learning	4.45 (0.30)	4.25 (0.34)	7.95 (1, 159)	.01	12.88 (1, 156)	.00
Problematic learning	2.07 (0.41)	2.39 (0.55)	7.9 (1, 159)	.01	9.54 (1, 156)	.00
Covariates						
Perceived value of LS in terms of learning outcomes	4.14 (.48)	4.32 (.44)			8.57 (3, 154)	.00
Perceived value of LS in terms of professional development.	4.23 (.73)	3.96 (.59)			3.78 (3, 154)	.01
		Model	4.82 (3,157)	.00	6.13 (3, 154)	.00
		Partial η^2		.08		.11

Abbreviations: df = degrees of freedom; M (SD) = mean (standard deviation).

Note: Alpha = .05

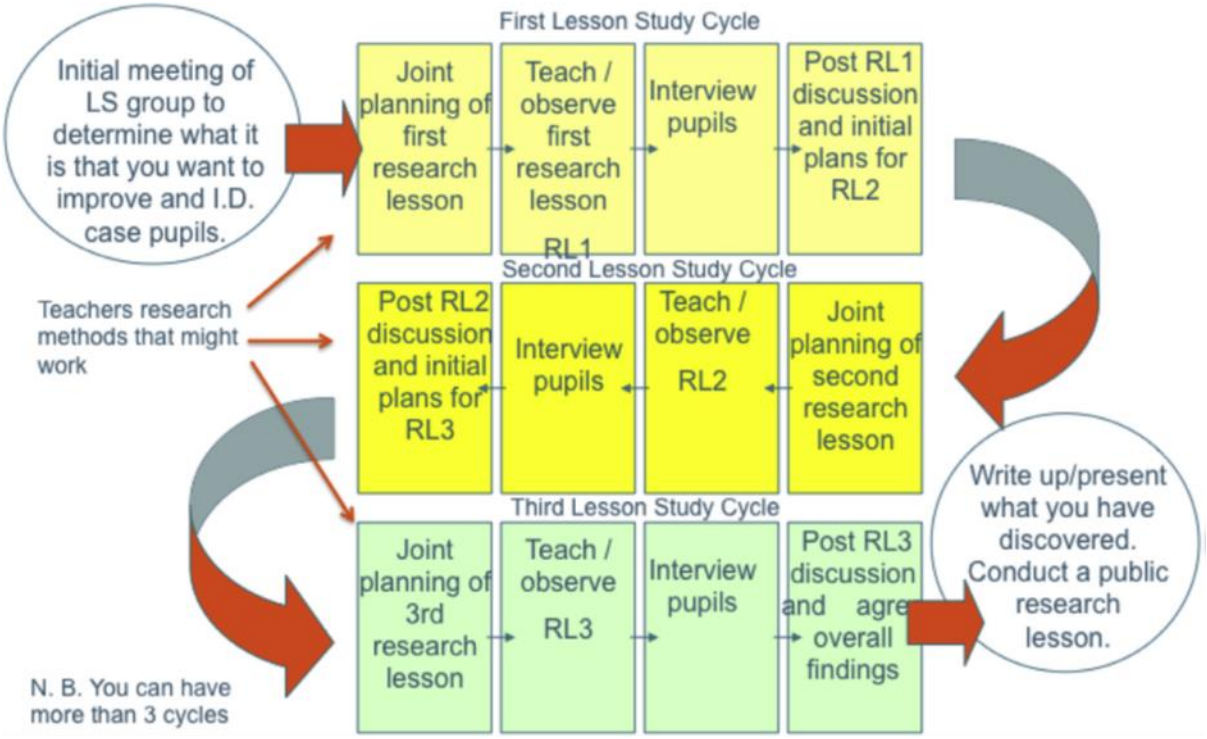

Figure 1. The Lesson Study process according to Dudley (2013)

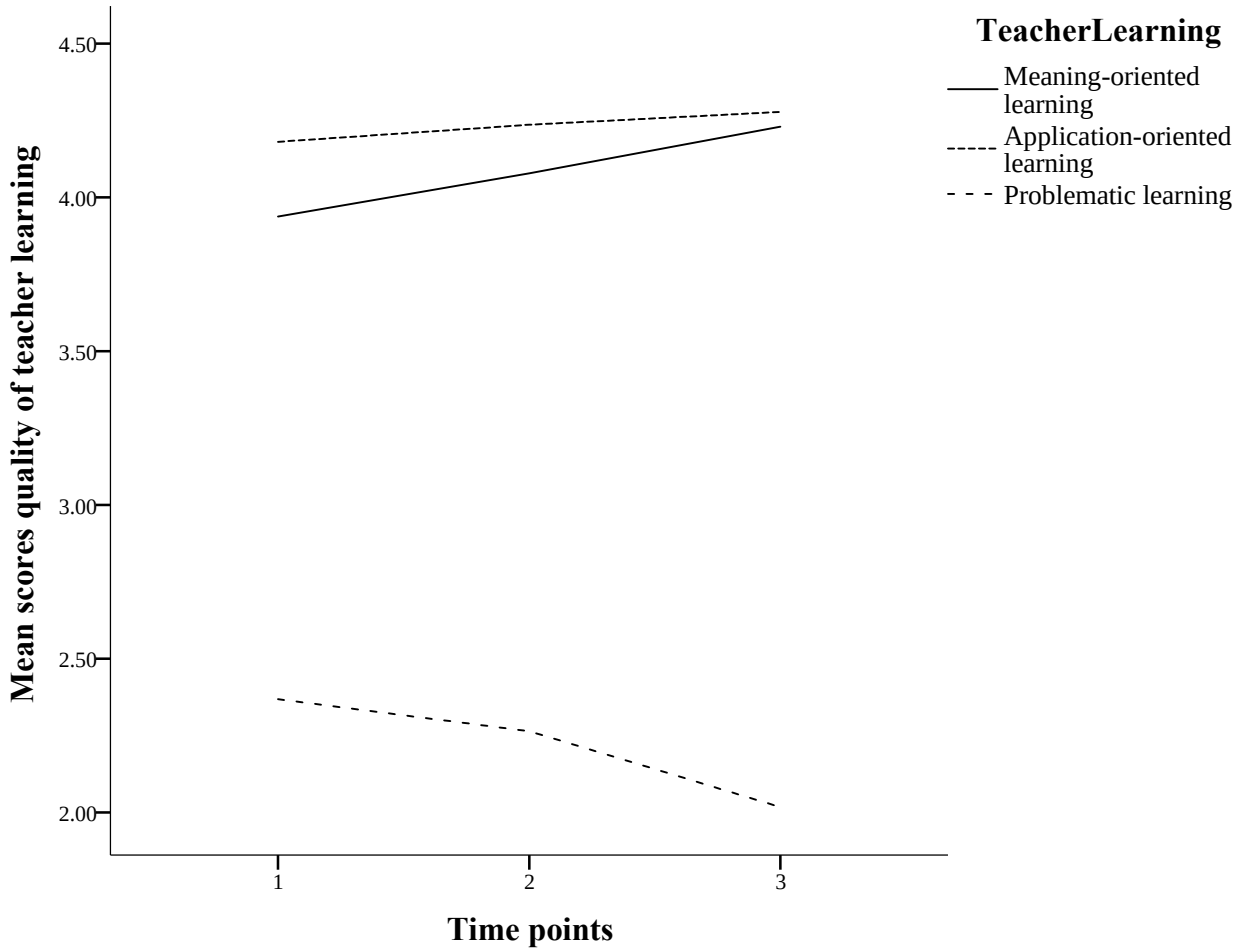

Figure 2. The development of teacher learning patterns over time

Note: Time points correspond to the times that inventories 1, 2 and 3 were administered.

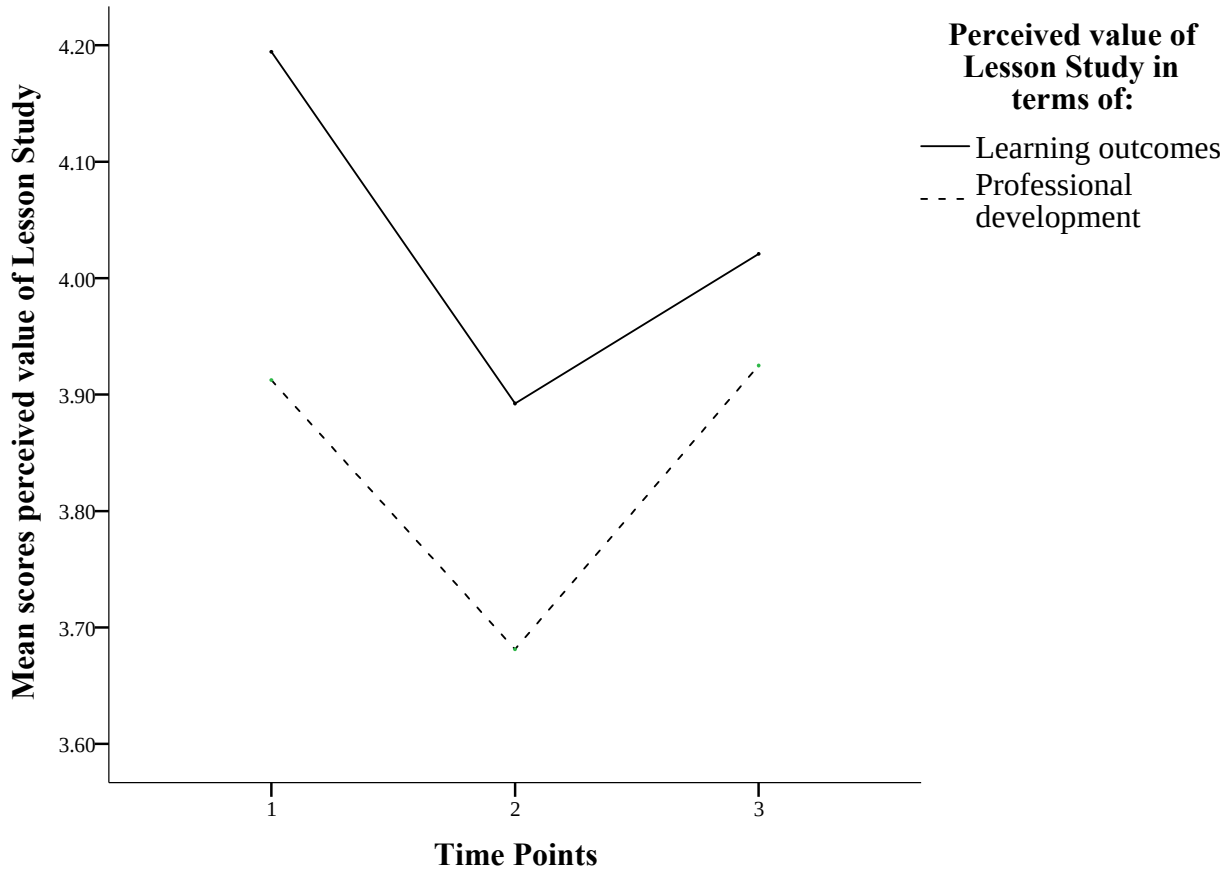

Figure 3. The development of perceptions of Lesson Study over time.

Note: Time points correspond to the times that inventories 1, 2 and 3 were administered.

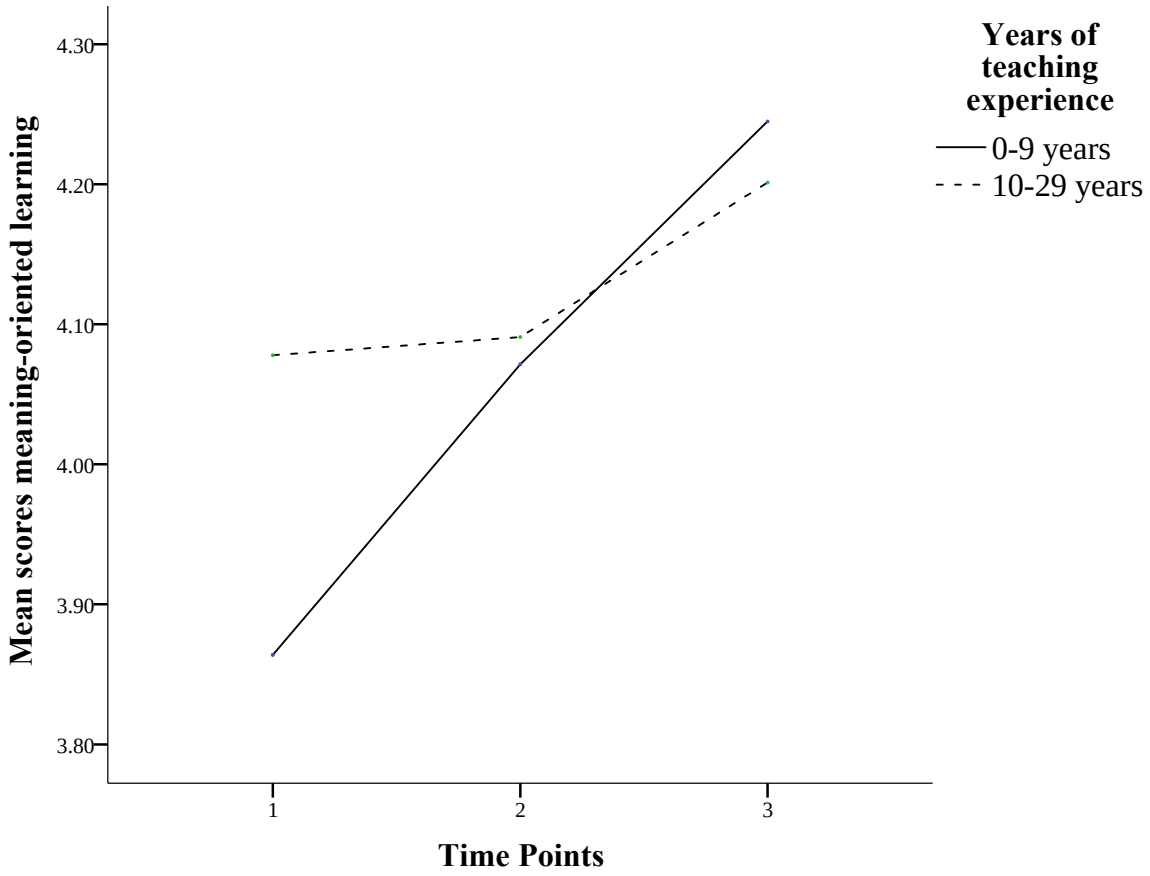

Figure 4. The development of meaning-oriented learning patterns for teachers with different levels of teaching experience.

Note: Time points correspond to the times that inventories 1, 2 and 3 were administered.