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ARTICLE

The development of research supervisors' pedagogical content knowledge in a lesson study project

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ABSTRACT

In this study, we aimed to identify how the learning activities elicited in a lesson study project contributed to self-perceived change in supervisors' pedagogical content knowledge (PCK). Lesson study is a method which combines both professional and educational development. During a lesson study project, teachers collaborate in a team and develop, teach, evaluate, and redesign a research lesson. During the 4-month lesson study project described here, four supervisors designed a protocol for research supervision meetings aimed at enhancing undergraduate students' learning. During the project, they experimented with open questioning and giving positive feedback instead of giving instruction and explanations. A mixed-methods design was used in this study. Data on the supervisors' learning activities and PCK were gathered using learner reports, video-recordings of meetings, and exit interviews. The analyses of these data showed that the lesson study project contributed to the development of the supervisors' PCK on instructional strategies and student understanding. The learning activity that contributed most to these changes was reflecting on their own practice and that of their students.

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Lesson study; teacher professional development; undergraduate students; research supervision; teacher-student interaction

Introduction

What research supervisors tend to do most when interacting with their students during research supervision, is intervene (Agricola et al. 2018). Diagnosing students' research skills and being able to supervise them adequately when interacting with them, demands specific supervisor knowledge. In this study, we examined how a lesson study project helped supervisors to develop such knowledge; we focused on supervisors' pedagogical content knowledge (PCK). We used lesson study as a specific form of action research in which research supervisors were in control of the practice situation and of the research process (Posch 2019; Soto Gómez et al. 2019).

In higher education, supervisors and students often have supervision meetings during the writing of their undergraduate thesis. These meetings offer opportunities for

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Supplemental data for this article can be accessed here.

supervisor-student interactions; supervisors can gather information about and diagnose students' understanding (Agricola et al. 2018). Supervisors can intervene with feedback, and students can ask questions to verify the feedback. For supervisors' feedback to be adaptive to students' needs, research supervisors need to diagnose students' research skills (de Kleijn et al. 2015). Diagnosing students' learning process is a complex process: teachers either do not use their diagnoses (Klug et al. 2013), have difficulties in diagnosing students' errors (Stahnke, Schueler, and Roesken-Winter 2016), overestimate student performance (Feinberg and Shapiro 2009), or intervene immediately (Agricola et al. 2018). We view research supervision as a teaching process for the supervisor (Bruce and Stoodley 2013; Franke and Arvidsson 2011). Within this teaching process, supervisors should provide opportunities for students to take an active role (Agricola et al. 2019). Students have positive perceptions about supervisors who increase student control, or stimulate them to think for themselves (Agricola et al. 2020). Supervisors need the knowledge about how a diagnostic conversation can be held."

Supervisors' pedagogical content knowledge

As early as in 1987, Shulman proposed categories of teacher knowledge. He distinguished between content knowledge, general pedagogical knowledge, curricular knowledge, knowledge of learners, of educational contexts, of educational goals, and pedagogical content knowledge. He described teachers' pedagogical content knowledge (PCK) as 'that special amalgam of content and pedagogy that is uniquely the province of teachers' (p. 8). Later Magnusson, Krajcik, and Borko (1999) distinguished five components of science teachers' PCK. We have adapted these five components of Magnusson, Krajcik, and Borko (1999) and refer to them as supervisors' PCK of research supervision: The first component is supervisors' *orientation to teaching* research courses; this component implies supervisors' general view about how they conceptualize research teaching. The second component is supervisors' *knowledge of the research curriculum*, including goals and objectives of the curriculum, as well as specific curricular materials. The third component is supervisors' *knowledge of students' understanding* of research; this refers to supervisors' knowledge about students' research skills, in order to help them develop these skills; and about which parts students find difficult. The fourth component is supervisors' *knowledge of assessment* of research skills; it concerns knowing which parts of the research skills are important to assess, as well as knowing which methods can be used to assess these research skills. The fifth and last component is supervisors' *knowledge of instructional strategies*; it is about knowing which specific strategies are useful to help students comprehend specific research concepts.

Interconnected model of professional growth

A model that is useful to analyze how supervisors' knowledge grows, is Clarke and Hollingsworth (2002) Interconnected Model of Professional Growth (IMPG). The IMPG represents the supervisors' professional world with four different domains: *the personal domain (PD)* with supervisor's knowledge, beliefs and attitudes; *the domain of practice (DP)* with supervisor's experimentation; *the domain of consequences (DC)* with consequences of supervisor's actions for student learning; and *the external domain (ED)* with sources of information like scientific articles or a training (see Figure 1).

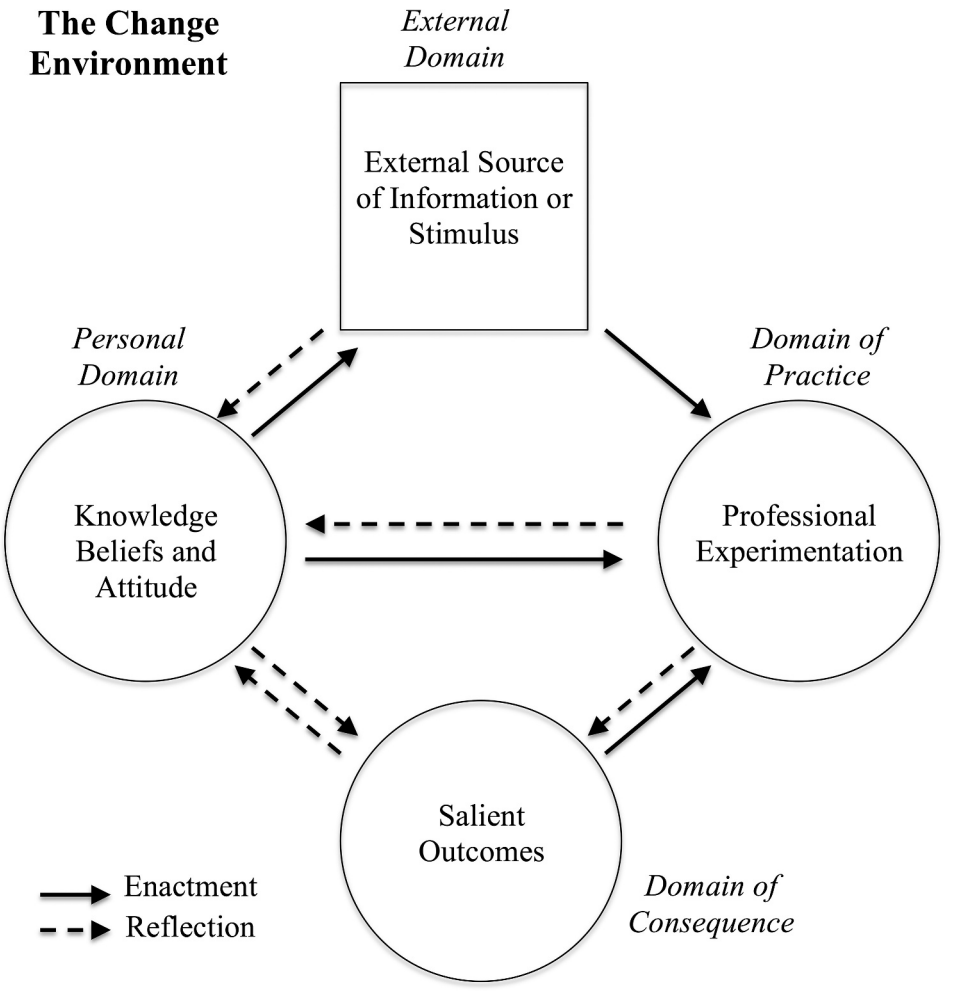

Figure 1. The interconnected model of professional growth (Clarke and Hollingsworth 2002).

The IMPG can be helpful for analyzing research data specific to each of the four domains, and is also helpful for the identification of patterns in teacher professional growth (Zwart et al. 2007). The general assumption is that teachers who receive a training, will increase their knowledge and beliefs, that will result in new teaching behaviour, and result in different student outcomes (Clarke and Hollingsworth 2002). Studies have shown that this is not how change in educational practice works (Bakkenes, Vermunt, and Wubbels 2010). Sometimes, teachers first test instructional techniques in classrooms and experience changes in student learning first-hand (Zwart et al. 2007). Only after student learning outcomes have become evident teachers' beliefs and attitudes are changed (Clarke and Hollingsworth 2002). In this study we view teacher knowledge and beliefs to be closely connected, but they can be differentiated within teachers' verbal expressions (Pajares 1992). When supervisor learning happens in one domain of the IMPG, it is often translated to another domain through the mediating processes of enactment

and reflection. Enactment is for example the translation process from something the supervisor knows, believes, or experienced, to supervisor's action in the domain of practice. Reflection is for example the translation process from an active and careful consideration of supervisor's action in the domain of practice to the gained knowledge in the personal domain. As a result, enactment can lead to a change in behaviour, and reflection to a change in cognition. Based on these different translation processes, a pathway of change can be constructed within the IMPG to illustrate supervisor learning. Clarke and Hollingsworth (2002) defined a pathway of change that existed of one or two translations between domains as a *change sequence*; these knowledge changes were considered as straightforward and superficial. They defined pathways of change with multiple change sequences (> 2) that last over time as a *growth network*; these knowledge changes were considered complex and lasting. Researchers have used the translation processes of the IMPG to describe secondary school teachers' professional development as a result of for instance a peer coaching trajectory (Zwart et al. 2007), a one-year post-graduate teacher education program (Justi and van Driel 2006), a one-year action research project (Wongsopawiro, Zwart, and van Driel 2017), and a lesson study project (Schipper et al. 2017).

Lesson study

Lesson study is a method for professional development in which teachers who want to improve aspects of the learning of their students collaborate in a team (Dudley 2013). We view lesson study as Soto Gomez et al. (2019) have conceptualized lesson study: 'as a nuanced expression of action research with enhanced value' (p.5); lesson study has an enhanced value as it aims to improve student's learning and as a consequence teacher's learning. Hanfstingl et al. (2020) argued action research and lesson study to be closely related; they have worked out similarities and differences between the both of them. One difference is that lesson study focuses specifically on the needs of learners, whereas action research uses more open questions and target groups (Hanfstingl et al. 2020). In a lesson study project, teachers develop, teach, and observe a research lesson and examine its impact on student learning (Lewis and Hurd 2011; Stepanek et al. 2006). When designing the research lesson, the participants are guided by a research theme. One team member teaches the research lesson while the others observe and collect data on student learning (Stepanek et al. 2006). After evaluating and adjusting the research lesson, another team member teaches the adjusted lesson (Verhoef et al. 2014). In general, teachers appreciate such a cyclical lesson study project, because they control the process and can adapt it to their own situation; they examine teaching and learning issues that matter to them; and the results can be directly applied in their own practice (Cerbin and Kopp 2006). The observation and focus on student learning in lesson study is the key to teachers' development (Cajkler et al. 2014). Lesson study can help teachers to develop the knowledge which they need to teach students (Lewis and Hurd 2011).

In this study, research supervisors participated in a lesson study approach and were mainly focused on student learning; whereas the authors of this study were mainly focused on supervisor learning. Following Bakkenes and her colleagues, we define supervisors' learning as 'an active process in which teachers engage in learning activities that lead to changes in knowledge and beliefs (cognition) and/or teaching practices

(behaviour)' (Bakkenes, Vermunt, and Wubbels 2010, 536). Bakkenes, Vermunt, and Wubbels (2010) distinguished several *learning activities* which can lead to teacher learning. A lesson study approach gives supervisors the opportunities to engage in these learning activities. We addressed the following research question: How does a lesson study approach stimulate the development of supervisors' PCK in students' research supervision?

Method

Participants and context

Lesson study teams are self-directed and require teachers (in our study supervisors) who want to learn together, to observe each other, and to teach in front of peers (Stepanek et al. 2006). The lesson study team consisted of five members, the facilitator and the four supervisors who agreed to participate; they worked at the same Dutch university. They supervised their students in their final year, and students worked in pairs and wrote their undergraduate thesis in the academic year 2016/2017. The participating supervisors and their students were all female; this was representative for the number of women teaching and attending this Bachelor of Health program (see Table 1). The students who were involved in the study were nearly the same age (S1: 21 years; S2: 22 years; S3: 23 years). Supervisors and students signed informed consent forms for observation and data gathering.

Lesson study intervention

As suggested by Stepanek et al. (2006), we used four phases when planning one lesson study cycle: (1) the preparation phase, (2) the teaching and observation phase, (3) the discussion phase, and (4) the evaluation phase (Stepanek et al. 2006; Verhoef and Goei 2015 August; Wood and Cajkler 2016). In total three lesson study cycles were completed. During these cycles, several instruments and materials were used and developed by the participants.

Measures of PCK and learning activities

Data on supervisors' PCK and learning activities were gathered using nine videotaped observations of the lesson study group meetings; four learning reports per supervisor; and an exit interview per supervisor. See Table 2 for an overview of all gathered data.

Table 1. Characteristics of participating supervisors.

Participant	Id	Alias	Age (years)	Education	Supervising (years)
Supervisor (S)	S1	Carrie	49	MSc	2
	S2	Samantha	34	MSc	9
	S3	Charlotte	46	PhD	7
	S4	Miranda	37	MSc	7
Facilitator (F)	F	John James	42	MSc	5

Table 2. Overview of data gathering during lesson study phases.

	LS Phase	Meeting	LS instrument	Measures	T1	T2	T3	T4
Cycle 1 March-May	Preparation	LS meeting 1	Discrepancy analysis					
		LS meeting 2	CIMO logic	Video observation 1 Learning report 1				
		LS meeting 3	LS preparation form	Video observation 2 Learning report 2				
		LS meeting 4	LS preparation form	Video observation 3				A
	Teach and observe	Research lesson	Observation form					
	Discussion	Teacher-student	Student interview					
	Evaluation	LS meeting 5	LS preparation form	Video recording 4 Learning report 3				
		LS meeting 6	CIMO logic	Video observation 5				A
Cycle 2 May-June	Preparation	LS meeting 7	LS preparation form	Video observation 6				A
	Teach and observe	Research lesson	Observation form					
	Discussion	Teacher-student	Student interview					
	Evaluation	LS meeting 8	LS preparation form	Video observation 7 Learning report 4				A N
Cycle 3 June- July	Preparation	LS meeting 9	LS preparation form	Video observation 8		A		
	Teach and observe	Research lesson	Observation form					
	Discussion	Teacher-student	Student interview					
	Evaluation	LS meeting 10		Video observation 9 Teacher interview		A		

Note. LS = Lesson Study; T = teacher; A = absent at LS meeting; N = learning report was not handed in

Videotaped observations of lesson study meetings

Nine preparation, discussion, and evaluation meetings were selected for a videotaped observation. The first lesson study meeting was not used for analysis as this meeting functioned as an instruction in which the facilitator presented and explained to the participants about the lesson study approach. During the lesson study meetings, the supervisors expressed and shared their PCK changes as statements of changed cognitions, beliefs, or practices, and their corresponding learning activities.

Learning report

A learning report was used, in which the supervisors were asked to describe a self-chosen learning experience with the help of four questions. The learning report was based on an existing learning report used to measure student teachers' learning and their learning experiences (Endedijk et al. 2014). The first question focused on the supervisors' PCK change: 1) 'What did you learn in the field of research supervision, what are your three most important insights?' In the second question, they were asked about their learning activities: 2) 'How did you learn this, for example, in which way, from whom, where, and

when?' And finally they were asked about the consequences for their practice: 3) 'What consequences does this learning experience have for your own research supervision?', and about 4) 'What consequences does this learning experience have for the students you supervise?' Participating supervisors were asked to fill in this learning report four times during the lesson study process.

Supervisor interview

The first author interviewed every participating supervisor at the end of the lesson study process. The interview guide was based on the open-ended questions of the learning reports. The interviewer asked some more specific questions, with input from the supervisor's answers in the learning reports.

Procedure and materials of the lesson study approach

Preparation phase

During the first preparation meeting, the supervisors conducted a discrepancy analysis (Stepanek et al. 2006). The supervisors brainstormed about a list of characteristics that an ideal student would be able to demonstrate during a supervision meeting: a student who pro-actively asked questions, took up responsibility, and took up their feedback. Then, the supervisors identified the characteristics for where students actual were: often a passive learner with roughly the opposite characteristics as the ideal one. The discussion about the ideal and actual student resulted in new student and teacher insights and input for the research theme: a lot of students did not show the desired behaviour, and the supervisors concluded that a reason for this was that they did not stimulate this behaviour. The discrepancy analysis resulted in a case student to focus on during the design of the research lesson.

CIMO logic. The participating supervisors used the Context Intervention Mechanism Outcome (CIMO) logic when designing the research lesson. Using the CIMO logic is preferred as it does not only specify the proposed Intervention and the desired Outcome; it also specifies the Context of the design, just as the Mechanism by which the outcome is achieved (Denyer, Tranfield, and Van Aken 2008). Specifying the design mechanism within the CIMO logic helps to understand how and why the intervention worked (Bronkhorst et al. 2011). Based on the CIMO logic, supervisors chose to merely use open questions and prompts; the student will have to substantiate, argue, and consider the choices he made. Student's own answers, arguments, and thoughts will give the student new insights and will give the student opportunities to take responsibility and have a feeling of independency. Supervisors aimed to answer the question: does supervisor questioning have a positive impact on student's pro-actively arguing, and on student's self-understanding of their research skills?

Literature. The facilitator selected some literature for the participants. An article about 'promoting students' research self-efficacy' (Overall, Deane, and Peterson 2011) and an article about 'adaptive teaching' (Van de Pol, Volman, and Beishuizen 2011) were sent as sources of inspiration for selecting a research topic. One article about 'instructional dialogues' (Ruiz-Primo 2011), and two articles about 'one-to-one tutoring' (Chi et al.

2001; Graesser, Person, and Magliano 1995) were sent as inspiration for possible interventions that could be used in the research lesson.

Design of research lesson. The supervisors designed the research lesson in which the new approach (questioning) was implemented. During the design of the research lesson the supervisors kept the case student in mind just as Dudley (2013) argued. Supervisors constructed a lesson preparation form for the research lesson, an observation form to evaluate student learning, and a small interview guide to evaluate student's perception of the intervention. The supervisors decided which supervisor would teach the research lesson, which case student typified the passive learner and would be invited for the research lesson, and which supervisor would interview the student.

Teaching and observation phase

The *teaching and observation* phase existed of the research lesson in which one of the supervisors was having the supervision meeting with the selected case student while the others observed the meeting and made notes with a focus on student learning (Dudley 2013; Saito et al. 2008). Next to the room in which the research lesson was delivered, the other three supervisors and the lesson study facilitator were sitting in the observation room. A one-way screen divided these two rooms. A microphone was placed in the research lesson room, and a speaker in the observation room. The observers observed and listened to the research lesson without disturbing the supervisor and student. The research lesson was videotaped. After the research lesson, one of the observers held an interview with the student using the interview protocol to evaluate student's learning experience of the experiment.

Discussion phase

The *discussion* phase existed of analyzing and discussing the research lesson: the supervisor observations were examined, as well the student interview and the experiences of implementing the research lesson (Demir, Sutton-Brown, and Czerniak 2012). Within this phase, all supervisors had to focus on their own observations compared to what they predicted, on the way students learned and the effect of teaching on students' learning, and how this could be improved next time.

Evaluation phase

The *evaluation* phase existed of a revision of the research lesson based on the supervisor observations and the student interview of the discussion phase. These data were used to make changes to the research lesson. Supervisors changed their instructional approach; they added positive feedback to the questioning strategy, leading to a new CIMO logic. During the second and third lesson study cycle, this new approach was implemented in new research lessons.

Data analysis

Transcripts

A research assistant transcribed all the nine videotaped observations and four interviews verbatim into simple transcripts. Videos were transcribed literally, with punctuation,

pauses, continuers (e.g. hm, yeah) and turn taking, but without intonation or non-verbal behaviour. In each transcript, a speaker received his/her own paragraph. We imported all transcripts and the learning reports into the qualitative data analysis software program NVivo® (QSR International Pty Ltd. Version 11, 2016).

Indicators of change

First, to find which PCK components had changed we followed Wongsopawiro, Zwart, and van Driel (2017) and Zwart et al. (2007) and searched in our data for *indicators of change in supervisor knowledge, practice or beliefs*. An indicator of change existed of a statement or utterance of the supervisor, as found in the learning reports, in the transcripts of the lesson study meetings, and in the transcripts of the exit interviews. Three different indicators of perceived change were coded: a statement was coded as an indicator of (1) *change in supervisor knowledge* when the supervisor used one of the following utterances: e.g., I have learned; I know how; I understand why; I believe now that. A change in supervisor practice was defined as a change in supervisor's perceived or intentional behaviour (Wongsopawiro, Zwart, and van Driel 2017). We coded a statement as (2) *change in supervisor practice* when the supervisor used one of the following utterances: e.g. Now I am doing; I used to do this but now I am doing that; I tend to do more; I am doing things differently now; I was surprised students liked it. Finally, we coded a statement as an indicator of (3) *change in supervisor beliefs* when the supervisor used one of the utterances: e.g. I am confident in; I feel that I now can. The codes were used in the analyses.

PCK components

Second, following Wongsopawiro, Zwart, and van Driel (2017) and Justi and van Driel (2006), we coded every indicator of supervisor change as one of the five PCK components for research supervision: (1) Supervisors' orientation to teaching research courses; (2) supervisors' knowledge of the research curriculum; (3) supervisors' knowledge of students' understanding of research; (4) supervisors' knowledge of assessment of research skills; and (5) supervisors' knowledge of instructional strategies. Each PCK component was coded as fitting in the Personal Domain (PD) of the IMPG.

Learning activities

Third, to determine which learning activities were, according to the supervisors, underlying the changes in PCK components, we searched for the learning activities the supervisors reported in relation to this change. These learning activities were often reported just before or right after the indicator of change/PCK component. Building on the activities of Bakkenes, Vermunt, and Wubbels (2010) we distinguished five learning activities: (1) supervisors can experiment in the supervising activity itself and try out a new supervising method; (2) they can interact with and get ideas from others, by observing and discussing with colleagues, and reading articles; (3) they can consider their own practice, and (4) student practice; (5) and experience friction between what is expected and what happens. Each reported learning activity was coded on one of these five learning activities.

Each coded learning activity was then coded as belonging to one of the three other domains of the IMPG: to the External Domain (ED), when the supervisor learned from

other supervisors during the lesson study meetings, or from reading literature; to the Domain of Practice (DP), when the supervisor learned from reflecting on practice during the research lesson or during their own supervision practice; or to the Domain of Consequence (DC), when the supervisor learned from reflecting on student learning or student functioning as a consequence of their acting.

Within our data we distinguished segments; a segment was defined as the coding of each PCK component with its learning activities. A new segment in the data occurred when a supervisor reported a new indicator of change and thus new PCK component. The PCK components were leading for the segmentation; sometimes the supervisors reported one or more learning activities before the specific PCK component was reported. In the lesson study observation data, more than one supervisor participated, and thus segmentation was also applied when another supervisor reported a new indicator of change (see Appendix A for the coding scheme of the coding procedure).

Translation processes

Fourth, the IMPG translation processes were coded. As each PCK component and corresponding learning activities were coded to one of IMPG domains, sequences were formed within each segment. Within these segments, we coded the IMPG translation processes as used by Justi and van Driel (2006) and Wongsopawiro, Zwart, and van Driel (2017) (see Appendix B).

Pathways of change

Fifth, pathways of PCK change were analyzed. For each PCK component that was reported, we determined in which domain the entry point occurred. Entry points were considered as the start of each pathway. The chronological order in which the supervisor reported a PCK component or a learning activity, determined the entry point. Change sequences and growth networks emerged based on the sequences of one or more translation processes. Often our supervisors reported different learning activities for each PCK component, and several change sequences were reported within each segment. We considered pathways with multiple change sequences (> 2) as more complex changes and defined them as a *growth network*. We illustrated several growth networks with a pictorial representation. These representations were described in detail based on teacher utterances from our data.

Audit trail

To maintain and ensure the quality of this study, an audit trail was carried out (Akkerman et al. 2008). The object of this validation procedure focused on all the steps of the data gathering and data analysis. The underlying question was whether the auditor could verify the research design, the procedure of data gathering and data analysis according to three criteria: visibility (transparency), comprehensibility, and acceptability. The first author acted as auditee and prepared the procedure and presented all the findings to the auditor, accompanied with a justification of all decisions made. An independent junior researcher acted as the auditor and conducted a formative audit. This type of audit meant the formative judgment of the auditor could be used to improve the study (de Kleijn and Van Leeuwen 2018). The audit report gave input to realize a more transparent method section, to adapt some steps in the analysis of data, and to describe some examples for the limitation paragraph in the discussion section (see Appendix C).

Results

Indicators of change

We coded 77 supervisor-reported indicators of change within our data, these indicators pertained to a change in their knowledge, practice or beliefs (see Table 3). Most indicators of change were reported as a change in supervisor knowledge (65 times); several changes in supervisor practice were reported (10 times); and some changes in supervisor beliefs (2 times). An example of an indicator of change in supervisor knowledge was: 'That's what I have learned, to stimulate students to figure out things themselves, to let them argue their work; I am trying to do that with open questions, but also when I am giving feedback on draft versions of their work' (Carrie; Exit interview).

PCK components

Each of the seventy-seven indicators of change was coded as a PCK component. Within the adapted framework of Magnusson, Krajcik, and Borko (1999), our supervisors reported three of the five different PCK components (see Table 3): (1) Knowledge of instructional strategies, e.g. 'I have learned how quickly I am giving feedback' (Samantha; Exit interview); (2) Knowledge of students' understanding of research, e.g. 'Students would like answers for all their questions, they want to know if they are on track' (Charlotte; Learning report2): and (3) Orientation to supervising research skills, e.g., 'During the lesson study meeting, Charlotte said to me: I would do it in the exact same way as you did; such a confirmation is giving me confidence' (Carrie; Exit interview). The PCK components of assessment and of curriculum were not reported by our supervisors.

Table 3. Frequencies and percentages of reported indicators of change, PCK components, and learning activities.

	Carrie	*Samantha*	*Charlotte*	*Miranda*	Total	
	f	*f*	*f*	*f*	*f*	%
Indicator of change in						
Supervisor knowledge	12	14	21	17	64	84.2
Supervisor practice	2	1	5	2	10	13.2
Supervisor attitude or beliefs	1	0	1	0	2	2.6
PCK component of						
Instructional strategies	10	10	17	12	49	64.5
Student understanding	3	5	9	8	25	32.9
Orientation to teaching	1	0	1	0	2	2.6
Assessment of research	0	0	0	0	0	0.0
Research curriculum	0	0	0	0	0	0.0
Learning activities						
Considering own practice	14	19	44	21	98	39.5
Considering student practice	13	14	36	25	88	35.5
Getting ideas from others	7	8	8	8	31	12.5
Experimenting	4	6	3	4	17	6.9
Experiencing friction	4	4	4	2	14	5.6

Note: % = percentage of total number of indicators of change/PCK components (n = 76) or learning activities (n = 248).

Learning activities

All PCK components outcomes were connected to the learning activities that were reported by our supervisors within the data. Within the framework of Bakkenes, Vermunt, and Wubbels (2010), our supervisors reported five different types of learning activities (see Table 3): (1) Considering own practice, when supervisors reflected on their own teaching practice, e.g. 'I would like to stay alert on not giving instruction immediately, but first asking the student what they already know or have searched for, or what they think is the best option' (Samantha; Learning report1); (2) Considering student practice, when supervisors reflected on student's learning or functioning e.g. 'Some students are really working independently, and searched for answers themselves' (Carrie, Exit interview); (3) Getting ideas from others, when supervisors took notice of the views or practices of other supervisors e.g. 'I have learned from discussing and observing the supervision meeting of the research lesson' (Charlotte; Learning report4); (4) Experimenting, when supervisors purposefully tried out a new teaching strategy or new approach in practice, e.g. 'Two students wanted to use a statistical test and I said to them: you first have to find out for yourselves, I can help you putting the data in the Statistical Package for the Social Sciences, but you really have to do it yourselves' (Carrie; Exit interview); and (5) Experiencing friction, when supervisors experienced a completely unexpected event or realized their usual teaching approach did not work any longer e.g. 'This experiment did not go as planned, students were not happy and frustrated on the short term, but hopefully in the long run, they become more independent' (Miranda; Learning report2).

Translation processes

We coded the PCK components and learning activities as belonging to one of the four domains of the IMPG. As a result, nine possible translation processes could be coded (cf. Figure 1). In total 207 IMPG translation processes were coded; the domain of practice was involved for 70.5% of the three most frequently coded translations (see Table 4).

Pathways of PCK change

Sixty-two pathways of PCK change were constructed for each supervisor, each data source, and each PCK component. Considering the PCK component, most pathways

Table 4. Frequencies of the nine IMPG translation processes between the four domains.

		Carrie	*Samantha*	*Charlotte*	*Miranda*	Total	
		f	*f*	*f*	*f*	*f*	%
1. DP to DC	Reflection	8	11	27	14	58	29.0
2. PD to DP	Enactment	10	7	19	10	47	22.2
3. DC to DP	Enactment	4	6	19	11	40	19.3
4. ED to PD	Reflection	4	5	7	3	19	9.2
5. PD to DC	Reflection	3	4	6	7	19	9.7
6. DP to PD	Reflection	3	2	4	3	14	5.8
7. DC to PD	Reflection	0	2	3	2	6	3.4
8. PD to ED	Enactment	0	1	2	0	3	1.4
9. ED to DP	Enactment	0	0	0	0	0	0.0

that were reported by our supervisors within the data were pathways for the PCK of Instructional strategies (37 times), and for the PCK of Student's understanding (22 times).

Within each data source, supervisors reported different entry points. Some supervisors first reported that they either changed their practice (12 times; entry point: domain of practice), or evaluated student outcomes (4 times; entry point: domain of consequence). Some reported they got new ideas from other supervisors or learned from reading literature (18 times; entry point: external domain). In most cases the entry point started within the personal domain (25 times); supervisors reported something they had learned.

Twenty-one change sequences were constructed; seven times with only one translation process, and fourteen times with two. We constructed forty-one growth networks with three or more processes; twenty-eight times a growth network existed of three processes; seven times of four processes; three times of five, one time of six, and two times of nine processes. In the next section we represent pictorials of four growth networks and on the PCK components of instructional strategies and student understanding.

Growth networks of PCK of instructional strategies

In Figure 2, two growth networks for the PCK of instructional strategies are represented. On the left, the growth network that was reported most frequently is represented. It had an entry point in the external domain, through the personal domain and domain of practice, and ended in the domain of consequence. Supervisors reported this pathway fourteen times, mostly in their learning reports. In Figure 2, this pathway is represented on the left and reported by Carrie during her second learning report. Carrie's PCK change originated with the four supervisors who discussed the design of the experiment for the first research lesson about the instructional strategy of asking questions (entry point; ED). Carrie got new ideas from the discussion with the other supervisors; it gave her insight of

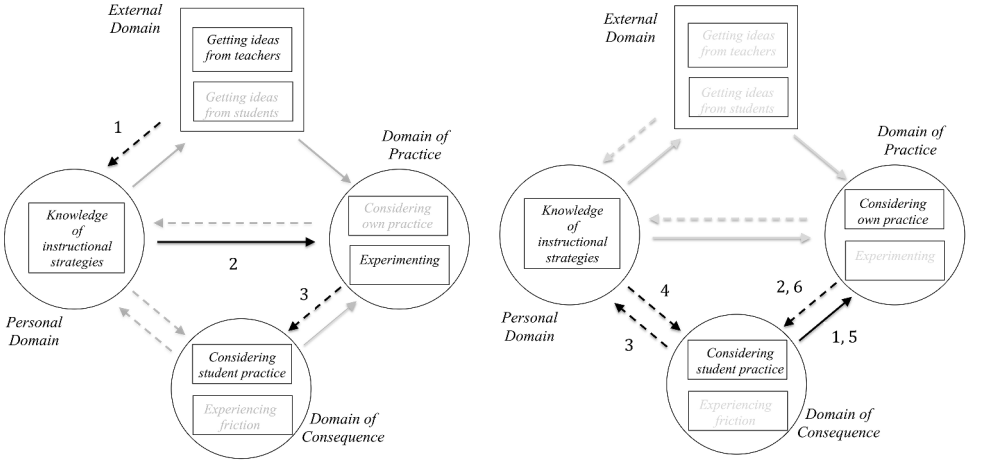

Figure 2. Representations of growth networks of the PCK of instructional strategies, one with four IMPG translation processes (Left/Carrie/Learning report2), and one with six processes (Right/Samantha/Observation1).

how to apply this strategy herself (PD). With this newly achieved PCK, Carrie experimented with her own students (DP), and evaluated student's reaction (DC).

We already showed in Table 4 that many translations were made from the domain of practice to the domain of consequence and vice versa (processes 1 and 3). The growth network on the right in Figure 2 illustrates these translations for the PCK of instructional strategies. The change took place during a lesson study meeting. In this meeting, Samantha discussed the dependent behaviour of a student she was supervising (entry point; DC). She reported her intervention of not just simply answering student's answers, but instead sending the student away with a new task (DP) and how the student reacted in a positive way, indeed showing more independent behaviour (DC). Then Samantha formulated what she learned about this experiment (PD), how hard the student was still trying (DC), and that Samantha applied the same intervention to other students (DP). She concluded that students can and should be independent learners (DC).

Growth networks of PCK of student understanding of research

In Figure 3, two growth networks of the PCK of student's understanding are represented. The network on the left, illustrates the longest pathway of PCK change in our data. This reported PCK change of Miranda originated during the second lesson study meeting. She discussed an experiment with the other supervisors in which she tried not to say anything to the students during their group meeting but instead let them take the initiative. She left the classroom on purpose (entry point; DP) with the aim to give room to the students. When she came back, she discovered this had worked, because students were working very hard (PD). But after a short while, one student asked Miranda what other topics would be discussed during their meeting (DC). Miranda responded by saying they could think of topics themselves (DP). In reaction, one of the students asked the other students to give feedback on a draft version of her work (DC). When no one answered, Miranda

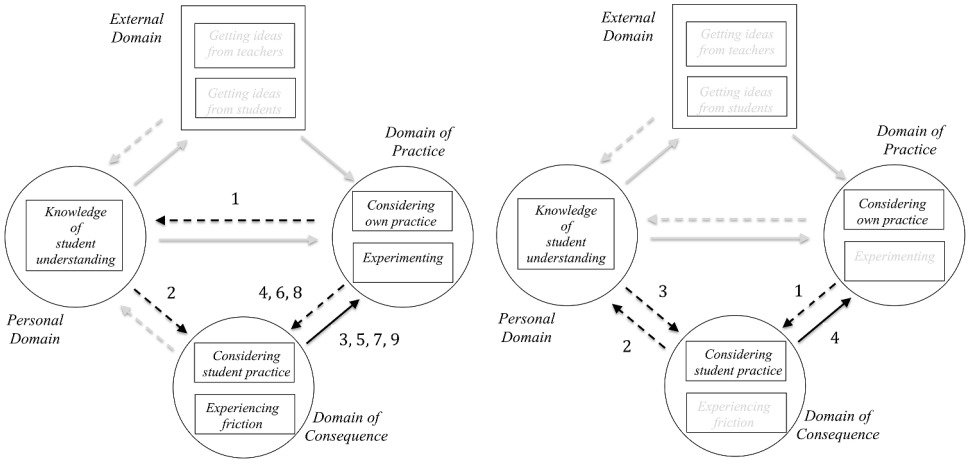

Figure 3. Representations of growth networks of the PCK of student understanding, one with nine IMPG translation processes (Left/Miranda/Observation2), and one with four processes (Right/Charlotte/Observation5).

tried to stimulate the other students to give an answer (DP). When reflecting on the meeting, Miranda argued that students were not able to act in a proactive way (DC). She mentioned that the next meeting could not continue without students actively participating (DP). Students asked if they could have an individual conversation with Miranda instead (DC), and again Miranda emphasized to them that setting up an agenda themselves is what was needed (DP).

The fourth growth network on the right illustrates Charlotte's PCK change of student understanding as result of the research lesson. The change originated during the sixth lesson study meeting, the evaluation of her own research lesson. Charlotte mentioned a conversation she had with two other students about the positive feedback she was giving to them (DP; entry point). Students appreciated the positive feedback Charlotte gave, however they became uncertain when she provided students several questions following that feedback (DC). Charlotte found it interesting that merely asking questions gave students a feeling of uncertainty (PD). In reaction to students' responses Charlotte explained her students why she used the strategy of asking questions (DP), although students showed understanding, they still feared failure (DC).

Discussion

In this study, we aimed to answer the research question 'How does a lesson study approach stimulate the development of supervisors' PCK in students' research supervision?' Within the data of the learning reports, meeting observations, and exit interviews, we analyzed supervisors' PCK and learning activities.

A change in supervisors' PCK of instructional strategies was reported most often. Supervisors reported they especially changed their PCK regarding asking questions and giving positive feedback on issues related to doing research. The finding of these two instructional strategies can be easily explained as they were the object of the lesson study approach. Asking questions and giving positive feedback were the two main instructional strategies the supervisors experimented with during the three research lessons, and as a result of that their PCK of instructional strategies changed. A change in supervisors' PCK of student understanding was the second component that was often reported. Supervisors reported they changed their PCK of students' dependent behaviour, of students' active participation, and their PCK of students' perception of negative feedback.

The main learning activities that changed supervisors' PCK were 'considering their own practice' and 'considering student practice'. These findings are in line with the results reported by Bakkenes, Vermunt, and Wubbels (2010), as the teachers in their study also reported considering their own practice as the most important learning activity. Furthermore, the learning activities of our supervisors were in line with the goals of the lesson study approach. Teachers developed, taught, and observed several research lessons, they considered student practice when examining its impact on students, and considered their own practice when evaluating these lessons together (Stepanek et al. 2006).

Although, the lesson study approach resulted in 21 change sequences, we found 41 growth networks indicating many complex changes of supervisors' PCK. The entry points of the growth networks started in all four IMPG domains; but especially in the personal

and external domain. This finding are in line with the results of Zwart et al. (2007), whose pathways had the most entry points in the personal and external domain as well.

In line with Wongsopawiro, Zwart, and van Driel (2017), we showed that the IMPG was useful to identify changes in research supervisors' PCK. When focusing on the constructed IMPG pathways, we can conclude that the professional growth of our research supervisors was not linear but existed of a complex network of translating processes. Clarke and Hollingsworth (2002) argued the domain of consequence plays a crucial role in the development of PCK. The knowledge pathways of our supervisors often involved the domains of practice and consequence.

Limitations

This study has some limitations. First, it was a small-scale study with one lesson study team and four participating supervisors, with the intention to understand supervisors' change in PCK. Therefore, generalization to other bachelor programs and/or other domains cannot be made based on our study. In primary education and secondary education, the lesson study approach has been studied more intensively. Lesson study has already shown to be an effective professional development program in primary education (Baricaua Gutierez 2016; Vrikki et al. 2017), and in secondary education (Cajkler et al. 2014; Verhoef et al. 2015).

Second, for optimal teacher learning during a lesson study approach, Dudley (2013) and Cerbin and Kopp (2006) recommended teachers to follow a procedure in which a focus on the student is emphasized. In our study, the supervisor of the second research lesson experienced some troubles in performing the experiment as designed beforehand. She started out with an open questioning strategy, just as planned, but when the student did not give any adequate responses in her perception, she failed to proceed with this strategy and fell back in giving instruction. Although, the supervisor learned a lot, and practiced even more indirect regulation than she was used to, the other participating observers could only focus on teacher performance during the evaluation meeting. This shifted focus from student to teacher may have hampered an impact of this second research lesson on supervisors' change of PCK. During the other two research lessons the supervisors did focus much more on how the student responded to the lesson, rather than on the teacher who happened to be teaching the research lesson.

Third, sometimes it is not very clear how different types of teacher knowledge can be distinguished; such as between PCK and general pedagogical knowledge. PCK represents an integration of knowledge types; it is a blend of content and pedagogy. Just as Magnusson, Krajcik, and Borko (1999) argued, it remains important to be aware that for PCK these boundaries are necessarily arbitrary and ambiguous.

Fourth, our approach of measuring teacher beliefs has been a simple way of the conceptualization of beliefs. We coded changes in teacher beliefs in our data by searching for utterances in which the supervisors expressed their confidence. We adopted this strategy from two other studies (Wongsopawiro, Zwart, and van Driel 2017; Zwart et al. 2007). When reasonable inferences are to be made about beliefs, then teacher's verbal expressions, predispositions to action, and teaching behaviours have to be measured (Pajares 1992). When changes in teacher beliefs are measured in future studies, – for

example when a new group of supervisors participate in a lesson study project – it will require a focus on what these supervisors say, intend to do, and actually do.

Implications and future research

Lesson study has proven to be a successful professional development programme for teachers who teach students in classrooms (Schipper et al. 2017; Verhoef et al. 2015). We added to that knowledge with the finding that lesson study is also suitable for designing face-to-face feedback conversations. The supervisors who participated in our study were able to apply indirect student-centred teaching strategies, to diagnose student understanding, and to empower students to think for themselves. The focus on student learning asked of participating supervisors has been shown to be the key learning aspect of this lesson study approach. Lesson study offered opportunities for supervisors to switch from their own repertoire to new supervising strategies. It would be interesting to investigate whether other lesson study teams could develop their PCK in the same way as our supervisors did.

The results of this study showed that the lesson study project was successful as an intervention with the aim to stimulate supervisors' PCK. A possible explanation for the success of this intervention is the intensive way in which the supervisors were guided in this four-month project. We had ten meetings, asked the supervisors to read literature, to develop their own instruments, and to write learning reports. Although one-shot, short-term interventions might be less effective than long-term interventions (Van Veen, Zwart, and Meirink 2012), we argue that future research could focus on ways to make this form of professional development less time-consuming. When supervisors do not have the appropriate diagnostic skills available, they could also be offered instruction during two-monthly video clubs (Van Es and Sherin 2010) or guided reflection meetings (McCullagh 2012). It would be interesting to investigate whether such professional development programmes can have the same impact as a lesson study project.

Conclusion

The results of this study add to the existing literature about lesson study, by showing that lesson study is a promising method for supervisor learning in higher education. We succeeded in showing that a lesson study intervention can have an impact on changes in supervisors' PCK in higher education. We encourage more research in higher education with the lesson study approach, and based on our results we expect other lesson study teams to develop changes in their PCK. This study showed that teachers supervising research assignments in higher education can experience different changes in their PCK as a result of their participation in a lesson study project. Supervisors' PCK changes were merely found for their knowledge of instructional strategies and their knowledge of students' understanding of research. Our supervisors followed different pathways for their PCK change. The key learning activities during the lesson study approach were supervisors' considerations of their own practice and their considerations about the practices of their students.

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References

Agricola, B.T., F.J. Prins, M.F. van der Schaaf, and J. van Tartwijk. 2018. "Teachers' Diagnosis of Students' Research Skills during the Mentoring of the Undergraduate Thesis." *Mentoring & Tutoring: Partnership in Learning* 26 (5): 542–562. doi:10.1080/13611267.2018.1561015.

Agricola, B.T., F.J. Prins, M.F. van der Schaaf, and J. van Tartwijk. 2020. "Supervisor and Student Perspectives on Undergraduate Thesis Supervision in Higher Education." *Scandinavian Journal of Educational Research* 1–21. doi:10.1080/00313831.2020.1775115.

Agricola, B.T., M.F. van der Schaaf, F. Prins, and J. van Tartwijk. 2019. "Shifting Patterns in Co-regulation, Feedback Perception, and Motivation during Research Supervision Meetings." *Scandinavian Journal of Educational Research* 1–22. doi:10.1080/00313831.2019.1640283.

Akkerman, S., W. Admiraal, M. Brekelmans, and H. Oost. 2008. "Auditing Quality of Research in Social Sciences." *Quality & Quantity* 42 (2): 257–274. doi:10.1007/s11135-006-9044-4.

Bakkenes, I., J.D. Vermunt, and T. Wubbels. 2010. "Teacher Learning in the Context of Educational Innovation: Learning Activities and Learning Outcomes of Experienced Teachers." *Learning and Instruction* 20 (6): 533–548. doi:10.1016/j.learninstruc.2009.09.001.

Baricaua Gutierez, S. 2016. "Building a Classroom-based Professional Learning Community through Lesson Study: Insights from Elementary School Science Teachers." *Professional Development in Education* 42 (5): 801–817. doi:10.1080/19415257.2015.1119709.

Bronkhorst, L.H., P.C. Meijer, B. Koster, and J.D. Vermunt. 2011. "Fostering Meaning-oriented Learning and Deliberate Practice in Teacher Education." *Teaching and Teacher Education* 27 (7): 1120–1130. doi:10.1016/j.tate.2011.05.008.

Bruce, C., and I. Stoodley. 2013. ";Experiencing higher degree research supervision as teaching." *Studies in Higher Education* 38 (2): 226–241. doi:10.1080/03075079.2011.576338

Cajkler, W., P. Wood, J. Norton, and D. Pedder. 2014. "Lesson Study as a Vehicle for Collaborative Teacher Learning in a Secondary School." *Professional Development in Education* 40 (4): 511–529. doi:10.1080/19415257.2013.866975.

Cerbin, W., and B. Kopp. 2006. "Lesson Study as a Model for Building Pedagogical Knowledge and Improving Teaching." *International Journal of Teaching and Learning in Higher Education* 18 (3): 250–257. Retrieved from https://files.eric.ed.gov/fulltext/EJ1068058.pdf

Chi, M.T.H., S.A. Siler, H. Jeong, T. Yamauchi, and R.G. Hausmann. 2001. "Learning from Human Tutoring." *Cognitive Science* 25 (4): 471–533. doi:10.1016/S0364-0213(01)00044-1.

Clarke, D., and H. Hollingsworth. 2002. "Elaborating a Model of Teacher Professional Growth." *Teaching and Teacher Education* 18 (8): 947–967. doi:10.1016/S0742-051X(02)00053-7.

de Kleijn, R.A.M., and A. Van Leeuwen. 2018. "Reflections and Review on the Audit Procedure: Guidelines for More Transparency." *International Journal of Qualitative Methods* 17 (1): 1–8. doi:10.1177/1609406918763214.

de Kleijn, R.A.M., P.C. Meijer, M. Brekelmans, and A. Pilot. 2015. "Adaptive Research Supervision: Exploring Expert Thesis Supervisors' Practical Knowledge." *Higher Education Research and Development* 34 (1): 117–130. doi:10.1080/07294360.2014.934331.

Demir, K., C. Sutton-Brown, and C. Czerniak. 2012. "Constraints to Changing Pedagogical Practices in Higher Education: An Example from Japanese Lesson Study." *International Journal of Science Education* 34 (11): 1709–1739. doi:10.1080/09500693.2011.645514.

Denyer, D., D. Tranfield, and J.E. Van Aken. 2008. "Developing Design Propositions through Research Synthesis." *Organization Studies* 29 (3): 393–413. doi:10.1177/0170840607088020.

Dudley, P. 2013. "Teacher Learning in Lesson Study: What Interaction-level Discourse Analysis Revealed about How Teachers Utilised Imagination, Tacit Knowledge of Teaching and Fresh Evidence of Pupils Learning, to Develop Practice Knowledge and so Enhance Their Pupils' Learning." *Teaching and Teacher Education* 34: 107–121. doi:10.1016/j.tate.2013.04.006.

Endedijk, M.D., M. Brekelmans, N. Verloop, P.J.C. Sleegers, and J.D. Vermunt. 2014. "Individual Differences in Student Teachers' Self-regulated Learning: An Examination of Regulation Configurations in Relation to Conceptions of Learning to Teach." *Learning and Individual Differences* 30: 155–162. doi:10.1016/j.lindif.2013.12.005.

Feinberg, A.B., and E.S. Shapiro. 2009. "Teacher Accuracy: An Examination of Teacher-based Judgments of Students' Reading with Differing Achievement Levels." *The Journal of Educational Research* 102 (6): 453–462. doi:10.3200/JOER.102.6.453-462.

Franke, A., and B. Arvidsson. 2011. "Research supervisors' different ways of experiencing supervision of doctoral students." *Studies in Higher Education* 36 (1): 7–19. doi:10.1080/03075070903402151

Graesser, A.C., N.K. Person, and J.P. Magliano. 1995. "Collaborative Dialogue Patterns in Naturalistic One-to-one Tutoring." *Applied Cognitive Psychology* 9 (6): 495–522. doi:10.1002/acp.2350090604.

Hanfstingl, B., G. Abuja, G. Isak, C. Lechner, and E. Steigberger. 2020. "Continuing Professional Development Designed as Second-order Action Research: Work-in-progress." *Educational Action Research* 28 (1): 71–82. doi:10.1080/09650792.2018.1490660.

Justi, R., and J. van Driel. 2006. "The Use of the Interconnected Model of Teacher Professional Growth for Understanding the Development of Science Teachers' Knowledge on Models and Modelling." *Teaching and Teacher Education* 22 (4): 437–450. doi:10.1016/j.tate.2005.11.011.

Klug, J., S. Bruder, A. Kelava, C. Spiel, and B. Schmitz. 2013. "Diagnostic Competence of Teachers: A Process Model that Accounts for Diagnosing Learning Behavior Tested by Means of A Case Scenario." *Teaching and Teacher Education* 30: 38–46. doi:10.1016/j.tate.2012.10.004.

Lewis, C.C., and J. Hurd. 2011. *Lesson Study Step by Step*. Portsmouth, NH: Heinemann.

Magnusson, S., J. Krajcik, and H. Borko. 1999. "Nature, Sources, and Development of Pedagogical Content Knowledge for Science Teaching." In *Examining Pedagogical Content Knowledge*, 95–132. Dordrecht: Springer.

McCullagh, J.F. 2012. "How Can Video Supported Reflection Enhance Teachers' Professional Development?" *Cultural Studies of Science Education* 7 (1): 137–152. doi:10.1007/s11422-012-9396-0.

Overall, N.C., K.L. Deane, and E.R. Peterson. 2011. "Promoting Doctoral Students' Research Self-efficacy: Combining Academic Guidance with Autonomy Support." *Higher Education Research & Development* 30 (6): 791–805. doi:10.1080/07294360.2010.535508.

Pajares, M.F. 1992. "Teachers' Beliefs and Educational Research: Cleaning up a Messy Construct." *Review of Educational Research* 62 (3): 307–332. doi:10.3102/00346543062003307.

Posch, P. 2019. "Action Research–conceptual Distinctions and Confronting the Theory–practice Divide in Lesson and Learning Studies." *Educational Action Research* 27 (4): 496–510. doi:10.1080/09650792.2018.1502676.

QSR International Pty Ltd. Version 11, 2016. *NVivo Qualitative Data Analysis Software*.
Ruiz-Primo, M.A. 2011. "Informal Formative Assessment: The Role of Instructional Dialogues in Assessing Students' Learning." *Studies in Educational Evaluation* 37 (1): 15–24. doi:10.1016/j.stueduc.2011.04.003.
Saito, E., P. Hawe, S. Hadiprawiroc, and S. Empedhe. 2008. "Initiating Education Reform through Lesson Study at a University in Indonesia." *Educational Action Research* 16 (3): 391–406. doi:10.1080/09650790802260372.
Schipper, T., S.L. Goei, S. de Vries, and K. van Veen. 2017. "Professional Growth in Adaptive Teaching Competence as a Result of Lesson Study." *Teaching and Teacher Education* 68: 289–303. doi:10.1016/j.tate.2017.09.015.
Shulman, L.S. 1987. "Knowledge and Teaching: Foundations of the New Reform." *Harvard Educational Review* 57 (1): 1–23. doi:10.17763/haer.57.1.j463w79r56455411.
Soto Gómez, E., M.J. Serván Núñez, N.P. Trapero, and Á.I. Pérez Gómez. 2019. "Action Research through Lesson Study for the Reconstruction of Teachers' Practical Knowledge. A Review of Research at Málaga University (Spain)." *Educational Action Research* 27 (4): 527–542. doi:10.1080/09650792.2019.1610020.
Stahnke, R., S. Schueler, and B. Roesken-Winter. 2016. "Teachers' Perception, Interpretation, and Decision-making: A Systematic Review of Empirical Mathematics Education Research." *Zdm* 48 (1–2): 1–27. doi:10.1007/s11858-016-0775-y.
Stepanek, J., G. Appel, M. Leong, M.T. Mangan, and M. Mitchell. 2006. *Leading Lesson Study: A Practical Guide for Teachers and Facilitators*. Thousand Oaks, CA: Corwin Press.
Van de Pol, J., M. Volman, and J. Beishuizen. 2011. "Patterns of Contingent Teaching in Teacher-student Interaction." *Learning and Instruction* 21 (1): 46–57. doi:10.1016/j.learninstruc.2009.10.004.
Van Es, E.A., and M.G. Sherin. 2010. "The Influence of Video Clubs on Teachers' Thinking and Practice." *Journal of Mathematics Teacher Education* 13 (2): 155–176. doi:10.1007/s10857-009-9130-3.
Van Veen, K., R. Zwart, and J. Meirink. 2012. "What Makes Teacher Professional Development Effective? A Literature Review." In *Teacher Learning that Matters*, 23–41. New York: Routledge.
Verhoef, N.C., D. Tall, F. Coenders, and D. Van Smaalen. 2014. "The Complexities of a Lesson Study in a Dutch Situation: Mathematics Teacher Learning." *International Journal of Science and Mathematics Education* 12 (4): 859–881. doi:10.1007/s10763-013-9436-6.
Verhoef, N.C., F. Coenders, J.M. Pieters, D. van Smaalen, and D.O. Tall. 2015. "Professional Development through Lesson Study: Teaching the Derivative Using GeoGebra." *Professional Development in Education* 41 (1): 109–126. doi:10.1080/19415257.2014.886285.
Verhoef, N.C., and S.L. Goei. 2015. "Lesson Study as a Tool for Teacher Learning: The Context of Combinatorial Reasoning Problems." Paper presented at the EARLI 16th Biennial Conference: Towards a Reflective Society: Synergies between Learning, Teaching and Research. August. https://ris.utwente.nl/ws/portalfiles/portal/16061258
Vrikki, M., P. Warwick, J.D. Vermunt, N. Mercer, and N. Van Halem. 2017. "Teacher Learning in the Context of Lesson Study: A Video-based Analysis of Teacher Discussions." *Teaching and Teacher Education* 61: 211–224. doi:10.1016/j.tate.2016.10.014.
Wongsopawiro, D.S., R.C. Zwart, and J.H. van Driel. 2017. "Identifying Pathways of Teachers' PCK Development." *Teachers and Teaching* 23 (2): 191–210. doi:10.1080/13540602.2016.1204286.
Wood, P., and W. Cajkler. 2016. "A Participatory Approach to Lesson Study in Higher Education." *International Journal for Lesson and Learning Studies* 5 (1): 4–18. doi:10.1108/IJLLS-08-2015-0027.
Zwart, R., T. Wubbels, T.C. Bergen, and S. Bolhuis. 2007. "Experienced Teacher Learning within the Context of Reciprocal Peer Coaching." *Teachers and Teaching: Theory and Practice* 13 (2): 165–187. doi:10.1080/13540600601152520.