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HIGHLIGHTS

- Approaches for knowledge co-construction in teacher learning groups: practice-based, research-informed, or research-based.
- Participation in teacher learning groups changes teachers' teaching and understanding of teaching.
- Supportive school leadership is suggested as a key factor for knowledge co-construction in teacher learning groups.

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ABSTRACT

We investigated approaches to knowledge co-construction in teacher learning groups (TLGs), changes in teaching and understanding of teaching perceived by TLG participants, and supportive and inhibiting conditions for knowledge co-construction in TLGs. Interviews with 39 teachers revealed three approaches to knowledge co-construction in TLGs based on the knowledge source used: practice-based, research-informed, and research-based. All teachers reported changes in teaching and understanding of teaching. Participation in research-informed and research-based teacher learning groups seemed to affect teachers' teaching and understanding of teaching more deeply than participation in practice-based groups. Supportive school leadership appeared as a key condition for teachers' knowledge co-construction.

1. Introduction

Research on professional development activities for teachers suggests that such activities are frequently seen as ineffective, generally reach only a small portion of the school teachers, and only have a short-term impact (Opfer & Pedder, 2011; Van Veen, Zwart, & Meirink, 2012). Furthermore, many teachers rate the impact of professional development activities as low; they see them as being disconnected from practice (Opfer & Pedder, 2011; Wei, Darling-Hammond, & Adamson, 2010). Professional development activities have shown to be more effective in affecting teachers' learning if they require active participation, collaboration, and are clearly connected to daily practice (e.g. Boud & Hager, 2012; Grangeat & Gray, 2008). Therefore, teacher networks for collaborative professional development activities are being set up more often, frequently initiated by schools, and with more attention to questions that are directly relevant for teachers (e.g. Boud & Hager, 2012; De Laat, 2012; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006; Vrieling, Van den Beemt, & De Laat, 2016). These networks of teachers, which we refer to as teacher learning groups (TLGs), are increasingly being set up as part of innovation initiatives in which teachers play an active role in collaborative knowledge construction (Coburn & Russell, 2008; Fogleman, Fishman, & Krajcik, 2006), and in which school development and professional development are linked (Goodyear & Casey, 2015; Kelchtermans, 2006; Little, 2005). In line with Huizenga, Handelzalts, Nieveen, and Voogt (2015) and Hargreaves and O'Connor (2017), in this paper co-construction of knowledge in TLGs is seen as a learning activity,

and is conceptualised as teachers collaboratively constructing knowledge, using different sources, such as the practical knowledge of colleagues, educational research literature, knowledge of external experts, and/or collaborative research activities.

Although research suggests that co-construction of knowledge potentially positively affects teaching practices and student achievement (Doppenberg, Bakx, & Den Brok, 2012; Kelchtermans, 2006; Levine & Marcus, 2010; Meirink, Imants, Meijer, & Verloop, 2010; Vescio, Ross, & Adams, 2008), little research reports on how co-construction of knowledge in TLGs is actually approached by participating teachers, with what kind of changes in teaching and teachers' understanding of teaching, and under which conditions. Therefore, the objective of the current study is to develop insights into approaches to, perceived changes in teaching and understanding of teaching, and conditions for co-construction of knowledge in TLGs and the use of the co-constructed knowledge in secondary schools.

2. Theoretical framework

2.1. Professional learning and collaboration

In many Western countries, the teaching profession has developed from teachers being individually responsible for the quality of teaching and student outcomes to a shared responsibility for providing education (Desimone, 2009; Sleegers, Bolhuis, & Geijsel, 2005). Therefore, a growing body of literature stresses the importance of a collaborative teacher culture, in which teachers have the professional space to share and discuss each other's teaching practices, and to experiment with innovative teaching in an environment that makes them feel safe to criticise and to be criticised by their colleagues, school leaders and students (Admiraal et al., 2016). Consequently, many schools have developed a culture that implies that teachers collaboratively develop, discuss, improve, share and evaluate teaching practices (Admiraal et al., 2016). Furthermore, a large body of research also suggests that teachers' professional learning is more effective if teachers participate collaboratively (c.f. Bubb & Earley, 2009; Opfer & Pedder, 2011; Van Veen et al., 2012). Along these lines, Admiraal et al. (2016) point out the importance of collaborative learning for teachers' professional learning.

In addition to this collaborative aspect of professional learning, in their metanalysis on teachers' effective professional learning, Timperley, Wilson, Barrar, and Fung (2007) found the use of an inquiry and knowledge building cycle to be a key factor. Many researchers claim that, for *professional* learning, teachers' practical knowledge should be connected with other types of knowledge, such as knowledge from research (e.g. Lillejord & Børte, 2016; Wieser, 2016). According to Lillejord and Børte (2016), teachers' professional knowledge draws on their practical and personal knowledge as well as knowledge from research. However, teachers experience a gap between research knowledge and practice, meaning they only utilise knowledge from research to a limited extent (e.g. Cain, 2016; Hiebert, Gallimore, & Stigler, 2002; Van Schaik, Volman, Admiraal, & Schenke, 2018; Weimer, 2008).

2.2. Co-construction of knowledge in teacher learning groups

One of the manifestations of teacher collaboration in professional learning is teacher learning groups (TLGs). They are seen as ways to contribute to the improvement of educational quality, and to achieve a culture of professional learning (e.g. Vangrieken, Dochy, Raes, & Kyndt, 2015). Literature uses a variety of concepts and terms for types of teacher collaboration, such as professional learning communities, teacher communities, teacher development teams, and communities of practice, as mentioned by Vangrieken et al. (2015) in their review study. Although the concepts are mostly vaguely defined and used interchangeably, several authors emphasise that these various concepts have in common that they refer to collaborative learning within a community context, originating from the vision that learning is a social process that takes place with others and in a specific situation (e.g. Stoll et al., 2006; Vangrieken et al., 2015; Vrieling, Beemt, & Laat, 2016). In this paper, we refer to these forms of collaboration as teacher learning groups (TLGs). In such groups learning occurs because teachers collaboratively construct knowledge, a process in which they use different sources — their own classroom experiences, research literature, experts, or own research activities (Hargreaves & O'Connor, 2017; Huizenga, Handelzalts, Nieveen, & Voogt, 2015).

Evaluations of TLGs or similar groups have concluded that they positively affect teaching practices (Darling-Hammond & Bransford, 2005), as well as individual teacher development and the collective capacity of schools (Achinstein, 2002; Grossman, Wineburg, & Woolworth, 2001). Furthermore, a small body of research shows the relevance and significance of co-construction of knowledge for teachers' professional development, and its positive impact on teaching and students' learning (Admiraal et al., 2016; Levine & Marcus, 2010; Vescio et al., 2008; Voogt et al., 2011).

2.3. The role of research in co-construction of knowledge

For teacher knowledge to become professional knowledge, teachers should ground their teaching practice in research evidence and insights (Ion & Iucu, 2014), but that can be done in different ways. With respect to the use of research knowledge, Ion and Iucu (2014) distinguish between instrumental, conceptual, and strategic research use. First, the instrumental model means that research can be used to solve practical problems in teaching, for example by providing pedagogical approaches. According to Cain (2015), a research-informed practice can be seen as reactive version of instrumental research use; teachers use existing research to inform practice. Second, the conceptual model indicates that research provides concepts, theories and views that indirectly inform practice. As shown by Cain (2015), teachers who acquire research knowledge use it to reflect on their experiences and teaching, individually and in discussion. Third, the strategic model infers that research is used to inform and justify decisions, mainly by policy makers. Through them, strategic research use possibly influences practice (Stevens, 2007).

However, in line with many other studies (e.g. Cain, 2016; Hemsley-Brown & Sharp, 2003), the review study of Van Schaik et al. (2018) showed that teachers experience inhibiting conditions at different levels when utilising research knowledge. For example, they report that research knowledge is about generic problems and not about problems teachers experience in teaching, and that the form in which research knowledge is presented makes it difficult to translate into improvements in teaching. Therefore, in response to the gap between educational research and teaching practice, the model that assumes that knowledge is produced in scientific research settings, followed by the application in practice, has come up for discussion (see e.g. Cain, 2015; Oancea & Pring, 2008). New perspectives on the relationship between educational research and practice have resulted in, for example, the emergence of teacher-researchers — teachers who investigate their own teaching in order to work in a more evidence-informed way. In-school practice-oriented research or teacher research is commonly seen as a promising activity for the professional development of both experienced and student teachers (Admiraal, Smit, & Zwart, 2013; Bartlett & Burton, 2006; Cochran-Smith & Lytle, 2009; Vrijnsen-de Corte, Brok, Kamp, & Bergen, 2013). Teachers

learn professionally through conducting practice-oriented research activities, because they acquire enhanced knowledge about the causes and consequences of their teaching (Bartlett & Burton, 2006; Vrijnsen de Corte et al., 2013; Timperley et al., 2007). Contrary to the reactive version of instrumental research use, Cain (2015) proposes this research-based approach as a more proactive model of instrumental research use: teachers perceive a problem and undertake research to solve it. In doing so, teacher-researchers construct new knowledge for teaching (Cochran-Smith & Lytle, 2009). Insights from research show that teacher research could benefit from collaboration with other colleagues or researchers (e.g. Broekkamp & Van Hout-Wolters, 2007; Schenke, Van Driel, Geijsel, & Volman, 2016). Research also shows that teachers who participated in collaborative practice-oriented research activities became more professional in their roles, both as teachers and researchers (Snoek & Moens, 2011; Vrijnsen-de Corte, 2013), and experienced an increase in critical attitudes to education and educational policy (Meijer, Oolbekkink, Meirink, & Lockhorst, 2013). Therefore, collaboration between teachers, and teachers and researchers is recommended (Baumfield & Butterworth, 2007; Cornelissen et al., 2014; Martinovic et al., 2012; Van Schaik et al., 2018).

2.4. This study

Co-construction of knowledge in TLGs seems to be a promising activity for promoting teachers' professional learning, as well as for using knowledge more and better for improving teaching. Yet, there is little insight into how knowledge co-construction is approached in TLGs and how it affects teachers' practices and views. Therefore, the goal of the current study is to gain insight into approaches to knowledge co-construction in TLGs, and whether and how these approaches lead to changes in the participants' teaching and in their understanding of what good teaching is. The third goal of the current study is to gain insight into which factors might promote or hinder the co-construction of knowledge in TLGs. The research questions of our study are:

1. Which approaches to knowledge co-construction are used in TLGs?
2. What are the changes teachers perceived in their teaching and their understanding of teaching as a result of their participation in a TLG?
3. What are inhibiting and supportive conditions for co-construction of knowledge in TLGs?

3. Method

3.1. Context of the study

This study was conducted in the context of a three-year research project with the aim of getting insight into ways of enhancing knowledge utilisation in secondary schools. This project was carried out by a consortium of two universities, a research centre, and six secondary schools in the Netherlands.

3.2. Participants

The participants were 39 teachers from 25 secondary schools in the Netherlands. Each teacher took part in a different teacher learning group (TLG), which we broadly defined as a group of teachers who regularly meet to discuss experiences, literature, or own research. Nineteen teachers participated in a TLGs in one of the six schools in the consortium. Six participants were found in the network of the research group, and fourteen participants were

found through an internet search via Google. The search terms used were professional learning community, knowledge network, learner network, research team and community of learners, in combination with the terms teachers and secondary education. The search was limited to the Netherlands. The TLGs could have different formats and could differ in nature and intensity. Teachers were selected who were willing and available to participate in the current study.

The teachers had an average teaching experience of $M = 16,26$ ($SD = 9,76$) years. The average years of participation of the teachers in the TLGs was $M = 2,92$ ($SD = 1,67$). The TLGs consisted of an average of $M = 10,71$ ($SD = 6,72$) participating teachers. Further, 33% of the teachers had a bachelor degree in education, 62% had a master's degree, and 5% had a PhD degree.

Of the TLGs, 11 were composed of participants from one school, and 28 of participants from different schools. Further, 12 of the TLGs had a subject-specific focus, and the other groups had a cross-curricular focus (see also Table 1). Twenty-five TLGs (64%) met monthly or even more frequently, whereas two TLGs (5%) met irregularly and unscheduled. An overview of the frequency of meetings in the TLGs is provided in Table 3. More detailed information about the teachers and the TLGs in which they participated is included in Appendix A.

3.3. Data collection

The participants were interviewed based on a pre-structured interview guideline. Prior to the interview teachers received the complete interview guideline. At the start of the interview, teachers provided some general data, such as age, teaching experience, topics of their TLG, group composition, etc.

In order to answer research question 1, the interview guideline included questions with respect to the type of knowledge that is co-constructed in the TLG, which knowledge sources are used, and whether the TLG was guided. In order to answer research question 2, the interview guideline included questions with respect to the influence of participation in the TLGs on the teachers' teaching and understanding of teaching, such as whether they had started teaching differently, and whether they had started looking differently at teaching and/or education? In addition, using a five-point Likert scale, teachers were asked to indicate to what extent they used the knowledge that was co-constructed in the TLG in their teaching ($1 = $ never, $5 = $ often). In order to answer research question 3, the interview guideline included questions concerning which factors influenced co-construction of knowledge and its use in practice, such as what teachers experienced as supportive and inhibiting conditions. All interviews were digitally recorded and verbally transcribed.

3.4. Data analysis

First, to structure the information from the interviews a matrix was set up with in the rows each case/teacher, and in the columns the characteristics of the TLGs and the elements from the interview guideline. Second, all relevant interview fragments from the transcribed interviews were clustered based on the elements an put into the cells of the matrix. Third, a cross-case analysis was conducted on the information in the matrix with the research questions in mind. We noted patterns in the type of approaches to knowledge co-construction of the TLGs, the changes in their teaching and understanding of teaching that teachers perceived, and conditions for knowledge co-construction in TLGs (Miles, Huberman, & Saldana, 2013). The quantitative data was analysed using descriptive statistics and added to the information from the interviews on perceived changes. The analyses were performed by

Table 1
Distribution of TLGs.

	Practice based		Research informed		Research based		Total
	Subject specific	Cross-curricular	Subject specific	Cross-curricular	Subject specific	Cross-curricular	
Teachers from one school	2	1	–	5	–	3	11
Teachers from different schools (within the same school board)	4	3	6	9	–	6	28
Total	6	4	6	14	–	9	39

Table 2
Distribution of themes over the TLGs.

Type of TLG	Subject-specific		Cross-curricular	
Practice based	Designing lessons for economics	Teaching methods for physics (2)	School organisation	
	Teaching methods for mathematics	Teaching methods for biology	School specific identity	
	Teaching methods for music		Human rights	
			Diversity	
Research informed	Pedagogical implications of new physics exam		Differentiating between students (2)	Causal and multi-perspective reasoning in human and society subjects
	Dynamic modelling in science		Result-oriented teaching	Continuing learning lines in language and arithmetic
	Designing practical assignments in physics		General pedagogical skills	Students with giftedness
	Various economic topics		Personalised teaching (2)	Teaching methods for beta subjects
	Migration in history (2)		Integration of refugees in education	Migration
			Academic writing skills in language	
Research based			Teaching methods for beta subjects	Language-focused subject-matter teaching
			Research skills in various themes	Differentiating between students (3)
			Use of apps in classroom	Continuous student progression (2)
			Result-oriented teaching	Improving guidance of student-teachers

Table 3
Frequency of meetings.

Frequency of meeting	Practice-based TLGs (N = 10)	Research-informed TLGs (N = 20)	Research-based TLGs (N = 9)	Total
Weekly	3	6	–	9
Every two weeks	–	–	3	3
Monthly	3	5	4	12
Less than monthly	3	8	2	13
Irregular and unscheduled	1	1	–	2

the first author and both process and outcomes of the analyses were discussed in the author team in order to enhance the reliability of the findings.

4. Results

4.1. Co-construction of knowledge in teacher learning groups

Three approaches to knowledge co-construction in TLGs were found: practice-based (10 groups, 25,6%), research-informed (20 groups 51,3%), and research-based (9 groups, 23,1%) (see also Table 1). TLGs were identified as practice-based when new knowledge occurred through exchanging practical and personal teacher knowledge, mainly based on experiences. In these, the participants themselves are regarded as the primary knowledge sources. TLGs were identified as having a research-informed approach to knowledge co-construction, when the teachers in these TLGs intentionally used external knowledge sources, such as research knowledge, in addition to their practical knowledge. Lastly, TLGs were seen as having a research-based approach when new knowledge predominantly occurred through co-construction of knowledge from own research activities or by participating in

various forms of research activities, such as research partnerships and action research.

An overview of the frequency of meetings in the TLGs is provided in Table 3. Twenty-five TLGs (64%) met monthly or even more frequently, whereas only two TLGs (5%) met irregularly and unscheduled. An overview of the knowledge sources used and the types of co-constructed knowledge per type of TLG is provided in Table 4.

4.1.1. A practice-based approach to knowledge co-construction in TLGs

In practice-based TLGs, knowledge is predominantly co-constructed through exchanging own knowledge, views, ideas, and experiences from participants. Based on this, lessons or teaching approaches were (re-)designed and applied in practice, and again evaluated in the TLGs. Teachers who took part in these TLGs mainly designed their lessons based on practical and personal teacher knowledge of the participants.

The following remark illustrates knowledge co-construction in practice-based TLGs:

> In our TLG we mainly design and try out new teaching methods for our own lessons. These experiments are recorded on video and discussed and evaluated during the meetings. These discussions are guided by an educational design expert from a university of applied sciences. (teacher from a practice-based TLG)

Of the ten practice-based TLGs, six (60%) had a subject-specific focus, and four (40%) had a cross-curricular focus (see Tables 1 and 2). Furthermore, three of the practice-based TLGs (30%) were guided by external experts. In one case, this was the previously mentioned educational design expert from a university of applied

Table 4
Overview of used knowledge sources and types of co-constructed knowledge in the TLGs.

TLGs	Predominantly used sources of knowledge	Co-constructed knowledge
Practice- based	Practical and personal knowledge from participants	Pedagogical content knowledge in various subjects (mainly new insights and concrete ideas for the teachers' own lessons)
Research-informed	External knowledge sources, such as research knowledge (academic literature, conferences, lectures, and participating external experts)	Pedagogical content knowledge and skills; skills in how to search for relevant academic information; knowledge about the organisation of schools; skills for mentoring new teachers
Research-based	Knowledge derived from collaborative research activities into a problem that is relevant for the participating teachers.	Knowledge and skills in conducting research; academic skills, such as utilising academic literature; pedagogical knowledge and skills (mainly cross-curricular, such as coping with differences between students, better formulating student assignments, student motivation, and the effect of using digital tools in classrooms)

sciences, who acted as coordinator and directed the process of knowledge co-construction. Seven TLGs (70%) were not guided by someone from outside the TLG.

What type of knowledge is co-constructed in practice-based TLGs? All teachers mentioned pedagogical content knowledge in various subjects, depending on the theme of the TLG. This knowledge mainly includes new insights and concrete ideas for their own lessons, on for example student assessments, modelling, use of digital tools, new examination programmes, and differentiation between students.

4.1.2. A research-informed approach to knowledge co-construction in TLGs

Teachers from twenty TLGs reported a research-informed approach to knowledge co-construction. External knowledge sources, such as research knowledge were, in addition to their practical knowledge, intentionally used as the primary knowledge source. This includes 1) academic literature that is read, such as research articles published in subject-specific or pedagogical magazines, educational books, or accessible online scientific journals, 2) conferences, lectures, and workshops that are visited jointly, and 3) participating external experts, such as university researchers, or teacher educators from universities of applied sciences.

The following remark from one of the teachers illustrates knowledge co-construction in research-informed TLGs:

"Every week we study a chapter of the book with insights from educational research, translate these insights into our own teaching practice, apply them in our own lessons, and during the weekly meetings we discuss our experiences and what we have learned from it". (teacher from a research-informed TLG)

Compared to practice-based TLGs, research-informed TLGs had a larger proportion of TLGs with a cross-curricular focus (see Tables 1 and 2).

In the co-construction of knowledge, thirteen research-informed TLGs (65%) were guided by someone from outside the school organisations, which is more than with practice-based TLGs. In most cases this was an educational expert from a university, who regularly participated in the TLG. Also, a greater variety in guiding roles was mentioned: chairman, coordinator, process-supervisor, providing theoretical input, and giving feedback on homework assignments. Furthermore, three TLGs were guided by someone from the school management, who mainly had a supervising and facilitating role. Their participation was highly appreciated by all three teachers. Two TLGs were guided by colleagues who were teacher-researchers. Lastly, two TLGs were not guided in co-constructing new knowledge.

Concerning the type of the co-constructed knowledge in research-informed TLGs, comparable to practice-based TLGs, the majority of teachers (75%) mentioned pedagogical content knowledge and skills, such as new teaching methods, and pitfalls in personalised learning. Five teachers (25%) also reported skills in how to search for relevant academic information, four teachers (20%) mentioned knowledge about the organisation of their schools, and three teachers (15%) mentioned skills for mentoring new teachers. The following remark illustrates the acquisition of teaching knowledge and skills:

"The type of knowledge I have acquired mainly concerns knowledge about how to motivate students for a certain subject in history. It has yielded new pedagogical knowledge, something in which I do not consider myself very strong. The meetings of the learning group always provide a few pedagogical variations, which can be almost immediately implemented in my own lessons. Furthermore, the presentation of my own series of lessons, and the feedback from my colleagues, has resulted in a higher level of teaching in my new lessons". (teacher from a research-informed TLG)

4.1.3. A research-based approach to knowledge co-construction in TLGs

Nine TLGs had a *research-based approach* to knowledge co-construction, which means that teachers co-constructed new knowledge by collaborative research activities into a problem that was relevant for the participating teachers. Where the other two types of TLGs showed a mixture of content, all research-based TLGs had a cross-curricular focus (see Tables 1 and 2). Teachers reported research topics such as teaching approaches, the use of digital tools in their teaching practices, and student performance.

Seven research-based TLGs (78%) were externally guided, mostly by university researchers. Compared to the other types of TLGs, this was the largest proportion. As with research-informed TLGs, in most cases the researcher participated in the TLG. The following roles of these researchers were mentioned: guiding the teachers in their research activities, familiarising them with how and where to search for literature, being critical of existing myths in schools, and thinking along, based on their expertise. One of these seven externally guided TLGs was part of a collaborative project between universities and schools for secondary education and was therefore composed of teachers and researchers. In this TLG, both teachers and researchers contributed their own expertise in the process of knowledge co-construction; the researchers were reported as having a guiding position.

Eight teachers (89%) mentioned that the type of knowledge acquired in research-based TLGs was about conducting research. Two teachers (22%) also mentioned having acquired academic skills, such as utilising academic literature, and one teacher mentioned having received more insight into the functioning of school organisations. Six teachers (67%) declared having acquired pedagogical knowledge and skills that are mainly cross-curricular, such as coping with differences between students, better formulating student assignments, student motivation, and the effect of

digital tools in classrooms. The following remark illustrates the acquisition of a combination of pedagogical knowledge and knowledge about doing research:

"In our TLG I gained knowledge about differentiation between students in my lessons. We chose this theme because it is a main topic in our school and it is connected to our interests. Due to the research results we gained more knowledge about how to motivate students through differentiation on instruction. Furthermore, due to the research activities, I gained research knowledge and skills, such as conducting and analysing a survey, using experimental and control groups, how to search for literature in which databases, and some basic research statistics". (teacher from a research-based TLG)

4.2. Perceived changes in teaching and understanding of teaching

Regarding the second research question, 'What are the changes teachers perceived in their' teaching and their understanding of teaching as a result of their participation in a TLG?', we first discuss changes in teaching and then changes in teachers' understanding of teaching, for each type of TLG.

4.2.1. Changes in teaching

Using a five-point Likert scale, teachers in the TLGs were asked to what extent they applied the co-constructed knowledge in their teaching (1 = never, 5 = often). Teachers reported a degree of application of M = 3.16 (SD = 0.92), N = 39. Teachers from research-based TLGs reported the highest degree of application (M = 3.55, SD = 0.53, N = 9), followed by teachers from research-informed TLGs (M = 3.11, SD = 1.05, N = 20). Teachers from practice-based TLGs reported the lowest degree of application (M = 2.90, SD = 0.88, N = 10). No significant differences were found.

Asked whether they had started teaching differently, 26 teachers (67%) indicated that they did so as a result of their participation in the TLG, and almost all of them (N = 36, 92%) mentioned they used the newly co-constructed knowledge in their own teaching practice. For teachers from practice-based TLGs, this mainly included the application of newly designed lessons, and to a lesser extent teaching approaches. Six of them (60%) mentioned pedagogical changes, such as connecting their lessons more to local social developments, more and different use of digital support, and different use of feedback in their lessons. Comparable pedagogical changes were reported by fourteen teachers from research-informed TLGs (70%) and six teachers from research-based TLGs (67%). Teachers from research-informed TLGs had started to design their lessons differently, such as with more differentiation between students, more differentiation and variety in the curriculum, changed practical assignments, for instance focussed on causal reasoning, changed homework control, formulating learning goals with students and evaluating them together, more self-regulated learning, and more and different use of feedback. Changes in teaching by teachers from research-based TLGs included applying problem-based education, learning through experiments, use of alternative teaching tools, more differentiation between students, and formulating learning goals with students and evaluating them together. Sometimes these were incidental changes, however, in most cases teachers indicated that these changes had become a structural part of their teaching practices. One of the teachers from a research-based TLG mentioned he changed assignments into research assignments for his students, and therefore started teaching research skills. The changes mentioned by the teachers in research-informed and research-based TLGs, indicate deeper and more varied alterations or even revisions in their teaching, in comparison to participants in practice-based TLGs.

However, thirteen teachers (33%), equally divided over the three types of TLGs, indicated no changes in their teaching, First, they indicated no changes because of a lack of time and own attention. Second, they reported reasons related to the character of the co-constructed knowledge, such as themes or topics changed too quickly, did not or not yet have a clear connection to the teaching practice, or the co-constructed knowledge was too revolutionary. And third, three teachers from research-based TLGs (33%) reported they had not started teaching differently, because their teaching practices matched with the outcomes of the research in their TLGs, so the co-constructed knowledge was already part of their teaching practice.

4.2.2. Changes in understanding of teaching

Besides changes in teaching, participating in a TLG also contributed to alterations in teachers' understanding of teaching. By understanding we mean their assumptions and beliefs about what good teaching and learning is. Due to their participation in the process of co-construction, 27 teachers (69%) indicated that their understanding of teaching changed, which mainly concerned their own role in teaching and the learning process of the students. Teachers from practice-based TLGs mentioned changes in understanding about specific educational insights or pedagogical approaches, such as a renewed focus on the importance of a more structured way of teaching, and the importance of students discussing subject matters with each other instead of explaining it to them. The following remark illustrates the change in understanding in practice-based TLGs:

"My understanding of my own role in teaching in the classroom is really changing. By nature, I am a traditional frontal teacher, but I have seen that I have to change this way of teaching. I have seen that it is important for my students to be involved in critical thinking and discuss topics with each other. Basically, this is a search for my own role in teaching and I am trying to shift more and more to a balance between frontally explaining subjects and a more active role for my students. The conversations in our teacher group and the examples of my colleagues have caused a change in this issue in particular". (teacher from a practice-based TLG)

Compared to teachers from practice-based TLGs, changes in understanding reported by teachers from research-informed TLGs concerned less an understanding of their own role in classroom teaching, but rather on their own position and attitude in the students' learning process, with a focus on student learning instead of teaching methods. They mentioned changes in understanding, such as of the importance of more personal reflection on the teaching process, of the necessity of more need-supportive teaching, and of the importance of being aware of what they want the students to learn. The following remark is from one of the teachers from a research-informed TLG, which also illustrates that a changed understanding is usually combined with a change in teaching itself:

"My changed understanding of what good teaching is, can best be described as a change from a focus on students in general to more attention to the individual development of each individual student. In particular, I have started looking at students with different eyes, and now sometimes accept that students are developing differently, in different stages, reaching different goals. Therefore, I am guiding each student differently, based on his or her specific needs. This understanding also reaches my other colleagues; together we now look differently at group assignments and divide students and groups based on students' skills in collaboration. We do not want to burden a student by

having him or her collaborate with someone who is not yet capable of doing so. That is certainly relevant for the high ability students my team is responsible for: these students have specific learning needs. We have started to share the understanding that it is important to focus on the individual students and their learning needs. I see that my colleagues are paying more attention to the differences in metacognitive skills of students, for instance in developing 'in-depth' and 'enrichment assignments', precisely to keep these students motivated." (teacher from a research-informed TLG)

As with practice-based and research-informed TLGs, six teachers from research-based TLGs (67%) indicated a changed understanding of the role of the teacher in the classroom, mostly as regards to the importance of differentiation and more student-oriented teaching. Moreover, these teachers explicitly mentioned a changed understanding of the connection between research and practice in relation to their own role. For example, they emphasized the importance of a more inquiring attitude, the role of research in general in the school, and the importance of doing research themselves. One teacher reported that he had become better aware of current developments in education due to his participation in a research-based TLG, and one teacher also mentioned that he had developed a more critical attitude towards his own teaching. Furthermore, four teachers (44%) explicitly mentioned a changed understanding of the importance of collaboration with colleagues in TLGs in order to continue in learning and professionalisation. The changed understanding is illustrated by the following remark:

"By going through the process of doing research myself, I have seen what research can contribute to the teaching practice. In my opinion, every teacher should go through such a process. It allows me to make a better distinction between the flow of theories, information and opinions in education. And it increased my willingness to critically consider why I teach the way I teach". (teacher from a research-based TLG)

4.3. Conditions for knowledge co-construction in TLGs

Based on the teachers' answers, we categorised the supportive and inhibiting conditions in seven categories: (1) collaboration, (2) time, (3) the organisation of the TLG, (4) the relevance of the co-constructed knowledge itself, (5) school leadership, and (6) guidance. An overview of the supportive and inhibiting conditions is presented in Table 5. Next to co-constructing new knowledge, we distinguish using knowledge in practice.

4.3.1. Collaboration in the TLG
The most mentioned category of supportive conditions for knowledge co-construction is the quality of the collaboration in the

TLGs. Teachers explained what they felt was part of good collaboration among the participants: being jointly motivated, being open to perspectives and ideas of others and new insights, daring to come out of your own comfort zone, collaborative skills, and willingness to share good and bad practices with each other. The following remark is illustrative:

"Important conditions are for example being motivated with each other, being open to the ideas of others, the willingness to leave your comfort zone. Through the many conversations, I discovered and accepted that my teaching needed to change. For years I did not express that my teaching needed improvement, because it was easier to say that my teaching was good enough. Therefore, daring to be open, accessible and vulnerable to each other is important for improving your own teaching through learning from each other". (teacher from a practice-based TLG)

For teachers from practice-based and research-informed TLGs, collaboration mainly concerned the process of co-constructing new knowledge, and to a lesser extent using it in practice. Teachers from research-based TLGs did not seem to make this distinction. Although teachers from all three types of TLGs stressed the importance of good collaboration, teachers from research-informed and research-based TLGs also indicated that social interactions and relationship between the participants within the TLGs were important for knowledge co-construction. It created a safe and constructive atmosphere, for instance through social contact, a positive atmosphere, the importance of strong ties, and mutual trust and engagement. This is illustrated by the following remark:

"An important condition is the willingness to give and receive constructive criticism and feedback. Therefore, it is necessary to approach each other with respect and appreciation in the learning group, in a safe and positive atmosphere, and that constructive questions are being asked (did you think about this, why did you choose, etc.). The atmosphere in the learning group between the participants was indeed safe and constructive from the start of our group". (teacher from a research-informed TLG)

A striking result is that only three teachers (8%) mentioned inhibiting conditions concerning this category for the process of co-constructing new knowledge, and four teachers (10%) for using it in practice. These conditions included the composition of the TLG, such as no involvement of experienced colleagues, and a lack of motivation and attention of other participants. However, this indicates that in most cases, teachers experienced good collaboration and valuable social interactions.

4.3.2. Time
The second category is conditions concerning time, which include sufficient facilitated time and jointly pre-scheduled

Table 5
Overview of number of experienced supportive and inhibiting conditions for knowledge co-construction in types of TLGs.

	Practice-based TLGs (N = 10)		Research-informed TLGs (N = 20)		Research-based TLGs (N = 9)		Total (N = 39)	
	Co-constructing new knowledge	Using in practice	Co-constructing new knowledge	Using in practice	Co-constructing new knowledge	Using in practice	Co-constructing new knowledge	Using in practice
Collaboration in the TLG	5 (1)	2 (2)	12 (1)	6 (1)	6 (1)	5 (1)	23 (3)	13 (4)
Time	3 (4)	5 (4)	6 (5)	3 (4)	3 (1)	7 (1)	12 (10)	15 (9)
Organisation of the TLG	2 (2)	2 (2)	8 (6)	6 (2)	1 (1)	2 (1)	11 (9)	10 (5)
Relevance of the co-constructed knowledge	3 (0)	0 (1)	4 (1)	8 (0)	1 (1)	2 (0)	8 (2)	10 (1)
School leadership	1 (1)	0 (1)	3 (1)	3 (1)	2 (0)	3 (0)	6 (2)	6 (2)
Guidance	0 (2)	1 (0)	3 (2)	0 (3)	2 (0)	0 (2)	5 (4)	1 (5)

Note: the numbers in the columns refer to the number of interviews in which a condition was mentioned as supportive. The numbers between ( ) refer to the number of interviews in which a condition was mentioned as inhibiting.

moments in the schools' timetables. The importance of these conditions is also illustrated by the finding that teachers mentioned a lack of time as one of the two main reasons for not yet having changed their teaching. Referring to conditions concerning time, teachers expressed the need for more facilitated time for the entire process of knowledge co-construction. Teachers lacking jointly pre-scheduled moments experienced this as an inhibiting condition. Teachers with jointly pre-scheduled moments for meeting with others expressed this as a supportive condition.

Although conditions related to time were mentioned to a lesser extent than group composition and collaboration, teachers indicated that a lack of time was experienced as the most important inhibiting condition for knowledge co-construction in TLGs. However, this only applied to practice-based and research-informed TLGs. Teachers from research-based TLGs also stressed the importance of sufficient and jointly scheduled time, but only two of them experienced this as an inhibiting condition. This can probably be explained by the fact that most teachers from research-based TLGs were sufficiently facilitated in time to engage with each other. And although only two indicated time to be an inhibiting condition, we consider their comments as relevant, as they explicitly and clearly stressed a lack of time for proper research. They often faced the choice between which activity or responsibility to prioritise. Moreover, they felt that school leaders lack awareness of the fact that research is time consuming; not only is sufficient time important, but also the availability of several lessons in succession in the school timetable. This shows that supportive and inhibiting conditions concerning time and school leadership are often closely connected. This can be illustrated by the following comment:

> "I actually miss my school leader's involvement. For me, involvement is that he wants to know what we are doing, monitors our progress, and provides us with the right facilities to do research. The first of these facilities is providing us with sufficient time within the school's timetable, because that is precisely how he can show that he values what we are doing". (teacher from a research-based TLG)

4.3.3. The organisation of the TLG

Comments referring to conditions with respect to the organisation of the TLG can be divided into three subcategories. The first group relates to comments expressing the necessity of the TLG to be organised in a structured way with clear goals. Inhibiting conditions that were expressed at this level make explicit that there is need to better structure meetings, define clearer goals, prioritise TLG meetings over other school-organisational meetings that are still often prevalent, and make the TLG more visible in the broader school organisation.

Second, other comments concerned the composition of the TLG. Teachers from TLGs with a cross-curricular focus, including teachers teaching different subjects, expressed such a composition as a stimulating condition for knowledge co-construction, because of the inclusion of different perspectives and expertise. Five teachers (42%) participated in subject-specific TLGs, composed of teachers teaching the same subject, expressed they missed that variety, and indicated this as an inhibiting condition.

And third, the frequency of meetings was indicated as a condition. Especially teachers who participated in TLGs that met frequently, such as weekly or every two weeks, experienced this as highly satisfying because of the continuation of the process, and it stimulated strong ties between the teachers.

4.3.4. The relevance of the co-constructed knowledge for practice

Teachers stressed the importance of the new knowledge that was co-constructed in the TLG to be closely connected to their teaching practice. This is illustrated by the finding that they mentioned the lack of a clear connection to teaching practice as one of the two main reasons for not yet having changed their teaching. This is also illustrated by the following remark from one of the teachers:

> "An important condition in our group is that it concerns concrete and practical knowledge, which is directly applicable in my teaching where possible. This means that during the next meeting we can immediately reflect on our experiences with what we have developed and can further improve our new practice". (teacher from a practice-based TLG)

These conditions include the importance of the co-constructed knowledge being concrete, relevant, practically applicable, of perceived ownership through jointly choosing topics, and of learning about a topic that is closely connected to yourself. Of the teachers from research-based TLGs, two teachers from research-based TLGs (22%) mentioned the knowledge should be relevant and specific enough in order to have impact on practice.

Compared to practice-based and research-based TLGs, teachers from research-informed TLGs experienced this mainly as supportive when it comes to applying the knowledge in practice. This condition is seldom mentioned as inhibiting, indicating that the process of knowledge co-construction in most TLGs concerns relevant and practically applicable knowledge.

4.3.5. School leadership

Many conditions indirectly relate to the responsibility of school leaders, such as time, organisation, and guidance. However, teachers also made comments explicitly referring to school leadership. These mainly concerned involvement with the TLG, the participants and the co-constructed knowledge. Teachers from practice-based TLGs and research-informed TLGs indicated that they experienced the respective school leader as supportive, but others mentioned a lack of support. Teachers from research-based TLGs only mentioned that they experienced supportive school leadership. One teacher participated in a research-informed TLG in which a school leader was also a participant. He experienced his participation as stimulating for knowledge co-construction, because it contributed to a connection of the topic to broader school themes, and the proximity of the school leader to the teaching practice. A teacher from a research-based TLG expressed the supportive school leadership as follows:

> "There is regular consultation between the TLG members and the management, and they sometimes also visit our meetings. In addition, they usually incorporate our conclusions into new school policy, or connect our research activities to new developments and educational change". (teacher from a research-based TLG)

When indicated as an inhibiting condition, teachers mentioned a perceived lack of involvement and monitoring by their school leaders. Also, some teachers perceived a lack of vision by school leaders on teacher learning and development; those school leaders did not recognise TLG activities as professional learning. As a consequence, the co-construction of knowledge in these TLG remained isolated and disconnected from other developments in their schools.

4.3.6. Guidance

Teachers from practice-based TLGs mainly commented on more internal guidance, such as school leaders, in order to connect the

knowledge co-construction to wider themes in the schools. However, most teachers who highlighted the importance of guidance participated in research-informed or research-based TLGs. Their reported supportive conditions concerned guidance from external experts, such as researchers from universities, who usually had the role to link research knowledge and skills to the teachers' personal and practical knowledge. Teachers from research-based TLGs mentioned guidance in a variety of research activities during the process, such as searching and finding relevant literature and analysing research results. All teachers who participated in research-based TLGs that were guided by an external expert indicated that this guiding could promote knowledge co-construction in TLGs. Comments from teachers from research-informed TLGs mainly concerned searching and finding relevant literature and the accessibility of research knowledge.

Almost all comments referring to guidance, experienced stimulating and inhibiting conditions concerned the process of co-constructing new knowledge, which indicates that guidance is especially important in searching and finding relevant research knowledge. Only two teachers from research-informed TLGs (10%) and three teachers from research-based TLGs (43%) experienced guidance in the process of using the co-constructed knowledge in teaching. Most other teachers from these types of TLGs expressed a lack of such guidance. This is illustrated by the next quote from one of the teachers from a research-based TLG:

> "The meetings in our learning community were guided by a researcher, especially when acquiring new knowledge. This was done by helping us to search relevant academic literature, give feedback on written documents and research designs, and process the research results. However, the application of the results mainly occurred in the teaching practice itself. It would have been good if the researcher had also helped us to reflect on the translation of the research results into practice. Unfortunately, we didn't take time for this". (teacher from a research-based TLG)

5. Discussion and conclusion

In this study we explored approaches to knowledge co-construction in teacher learning groups (TLGs), changes that TLG participants perceived in their teaching and understanding of teaching, and supporting and inhibiting conditions for knowledge co-construction in TLGs.

We distinguished between three main approaches to TLGs on the basis of the intentionally used primary knowledge source: a) practice-based, in which knowledge co-construction occurred through sharing practical and personal knowledge, b) research-informed, in which the teachers intentionally used external knowledge sources, such as research performed by others, and c) research-based, in which knowledge co-construction predominantly occurred through conducting research activities or by participating in various forms of research activities, such as research partnerships and action research. This distinction of three types of TLG can be useful in further research, as well as practical applications by school leaders, teachers and policy makers.

Almost all teachers used the newly co-constructed knowledge in their teaching practice, mainly through the application of newly designed lessons. Also, particularly teachers from research-informed and research-based TLGs appeared to have changed their understanding of their own role in the learning process of students (see also Meijer et al., 2013), and of the value of enriching their own knowledge with new educational knowledge and insights from others, such as research knowledge. In line with Cain

(2015) and Ion and Iucu (2014), our study suggests that research knowledge can inform practice directly, through changes in teaching (instrumental research use), as well as indirectly and in a deeper sense, through changes in understanding of teaching (conceptual research use).

Concerning the third research question, we found six clusters of conditions for knowledge co-constructions in TLGs: 1) collaboration in an atmosphere of collegiality and openness, 2) sufficient jointly pre-scheduled time, 3) close connection of the co-constructed knowledge to teaching practice, 4) a structured organisation of the TLG, 5) supportive school leadership, and 6) guidance by an expert.

These results show that all three types of TLGs can contribute to a culture of professional teacher learning in TLGs and on a research culture in schools. However, we found differences between the three types of TLGs.

Practice-based TLGs seem to contribute to a culture of professional learning between the teachers in the TLGs, because teachers learn with and from each other, through exchanging their knowledge and co-constructing new lessons based on this. However, according to Lillejord and Børte (2016) and Wieser (2016), professional learning requires connecting teacher knowledge to other types of knowledge. In line with findings from Pareja Roblin, Ormel, McKenney, Voogt, and Pieters (2014), our study shows that in research-informed TLGs, teachers connected teacher knowledge with knowledge from research. In research-based TLGs teachers connected their existing knowledge to research knowledge and to new knowledge from own research activities. As a result, besides changed teaching practices through co-constructing new lessons, teachers from research-informed and research-based TLGs also turned out to have a changed understanding of their own role as teachers in the learning process of students; they used research knowledge to reflect on their teaching practices (see also Cain, 2015). Furthermore, they started to consider their own practices with a more inquiring attitude (see also Cain, 2015; Hargreaves & Fullan, 2012), and additionally acquired research skills in research-based TLGs. Although guidance by external experts, usually educational researchers, was mostly limited to connecting research knowledge and skills to teacher knowledge and experience, it was therefore highly valued as a supportive condition for knowledge co-construction in these types of TLGs.

The insights of our study align with the conclusions from Goodyear and Casey, (2015), who show that teachers are more apt to change their teaching practices in schools with strong professional learning communities than in schools in which they are more isolated and experience less guidance and support. Our study suggests that research-informed and research-based TLGs guided by external experts and supported and facilitated by school leaders can be such strong communities in themselves.

In conclusion, our study suggests that practice-based, research-informed, and research-based TLGs can be promising structures in contributing to a school culture of professional learning. However, there are indications that changes in teaching and understanding of teaching in research-informed and research-based TLGs are more comprehensive, because a wider variety of knowledge sources is used. Therefore, the effects of practice-based TLGs could be deepened by connecting teacher knowledge to external insights, such as knowledge from research. Because of the connection between teacher knowledge and knowledge from research, research-informed and research-based TLGs also contribute to connecting research and practice. However, in line with others (e.g. Kelchtermans, 2006; März, Gaikhorst, Mioch, & Geijsel, 2018; Moolenaar & Sleegers, 2015; Pareja Roblin et al., 2014; Vrijnsen-de Corte et al., 2013), we conclude that the conditions found to be important need to be considered to establish a culture of

professional learning. Among them, the facilitating, stimulating and monitoring role of the school leader can be seen as a key condition (see also Gurr, 2017; Hallinger, Piyaman, & Viseshsiri, 2017; Robinson, Lloyd, & Rowe, 2008).

5.1. Limitations and further research

First, in our study we only collected self-reported data; therefore, the results are based on teachers' perception of knowledge co-construction in their TLGs. It is thus possible that teachers in research-informed or research-based TLGs apply research knowledge in practice, however, in an incomplete or incorrect way, in a wrong context, or inadequately translate the results from their research activities into their teaching. In such cases their teaching does not improve. Further research, for instance using observations or student evaluations could offer insights into how and if the co-constructed knowledge affects teaching, and, as a consequence, student learning. The same is true for our conclusion that school leadership can be seen as a key condition for knowledge co-construction in TLGs. This conclusion is only based on the teachers' perception, and does not take the perspective of school leaders themselves into account. In order to get a better picture of what leadership practices lead to promoting knowledge co-construction in TLG, further research should take the perspectives of school leaders into consideration.

Second, in our data collection we interviewed only one person per TLG in order to include a substantial number of TLGs in our study. Yet this approach implies that other teachers of each group might have different perceptions of knowledge co-construction of the particular teacher group. Further research collecting data from a complete group as well as using document analysis and observations of the meetings could provide a more comprehensive picture of teachers' knowledge co-construction.

Third, the aim of our study was to examine approaches, benefits and conditions of knowledge co-construction. As a consequence, we did not examine the process of co-construction in the TLGs, i.e. what actually happens when teachers co-construct knowledge, and what are actually the benefits of constructing knowledge collaboratively instead of individually. Further research could focus more on the process of knowledge co-construction in TLGs, for instance by using dialogues or observations. Although there are studies that focus on such processes (e.g. Rytivaara & Kershner, 2012), further research incorporating our three approaches, could provide deeper insights in what teachers actually do within practice-based, research-informed, and research-based approaches to knowledge co-construction in TLGs.

Finally, our focus was on the benefits for individual teachers in a collaborative context. However, there may be collective outcomes as well. Interviews with more teachers per TLG could provide insight in such collective outcomes.

5.2. Implications for policy and practice

This section discusses implications on several levels, concerning (1) policy makers in education, (2) school leaders, (3) teachers in teacher learning groups, (4) teacher education, and (5) guidance. First, for policy makers in education, our study suggests the importance of stimulating schools and enabling teachers to learn through knowledge co-construction in TLGs. Time-related conditions are a concern; sufficient time for teachers is needed to meet in constellations of knowledge co-construction (see also e.g. Admiraal et al., 2016). Furthermore, our study also demonstrates how research knowledge can have an impact on practice and changes in teaching. In the Netherlands, collaboration between teachers and researchers, or on a more institutional level, between schools and research institutes, is considered a way to connect both types of knowledge and to increase the impact of educational research on teaching and teachers.

Second, in order to create a culture of professional learning, school leaders should concentrate on creating, facilitating and monitoring types of TLGs, stimulating teachers to connect their teacher knowledge to knowledge and insights from research, in combination with recognising and rewarding them as types of professional learning activities in their schools. In line with our review study (Van Schaik et al., 2018), in which we concluded that connecting schools and research institutes could be a way to foster the use of research knowledge by teachers, our current study indicates that this can take a practical form by connecting to existing TLGs or creating new ones. Furthermore, an increasing number of professional networks such as TLGs are set up as part of innovation initiatives in which teachers take an active role in knowledge co-construction and the design of the innovation (Coburn & Russell, 2008; Gardner, 2011). März et al. (2018) concluded that such professional networks provide opportunities for connecting professional learning and school development. For this, our study implicates that preferably research-informed and research-based TLGs have to be considered.

Third, for continuing in professional learning, teachers should search for opportunities to connect to existing research-informed or research-based TLGs, create new ones themselves, or adjust their practice-based TLG towards a more research-informed or research-based approach, in order to link their own knowledge on several subjects to what is known from research. In this context, Vrieling et al. (2016) stressed the importance for all teachers to be actively involved in TLGs. Therefore, teachers should be aware of the importance of being jointly motivated and open to each other, and — when necessary — invest in mutual engagement and relationship within the TLGs. This aligns with the concept of 'team psychological safety', as described by Edmondson, Kramer, and Cook (2004, p. 241), which was found to be one of the most important predictors of team learning behaviour by Raes, Kyndt, Decuyper & Van den Bossche (2015). Furthermore, the experienced inhibiting conditions often correspond between TLGs. Therefore, teachers could connect with teachers from other TLGs, and see if they can learn how to solve or deal with these issues from other groups.

Fourth, referring to teacher education, our study implicates the need for preparing pre-service teachers for practice-based, research-informed and research-based types of knowledge co-construction, providing them with skills in connecting educational research and their teaching practice, and developing skills for action research in their own teaching practice.

Lastly, our study suggests that guidance of TLGs by external experts, such as researchers from universities, enables the connection between teacher knowledge and research knowledge, and therefore promotes professional learning. However, where guidance seems to mainly concentrate on providing external knowledge sources, it should also focus on the co-construction of knowledge and using it in practice. In this context, Goodyear and Casey (2015) state that such external actors can best act as *boundary spanners*, who are able to connect theory and practice. They bring research knowledge into the school and stimulate teachers to connect this with their teaching. In this way, they can stimulate and facilitate research-informed or research-based practices of knowledge co-construction through their outsider perspective.

Appendix A. Characteristics of teacher learning groups and teachers

	Teacher learning groups (TLGs)							Teachers					
	Focus: subject-specific/ cross-curricular	Composition: One school/ different schools	Number of Teachers	Frequency of meetings	Current topic of the TLG	How the TLG was initiated	Guidance	How selected	Teaching experience (years)	Participation in the TLG (years)	Gender	Age	Academic degree in education.
Practice-based TLGs													
1	Subject-specific	One school	4	Weekly	Designing lessons for economics	Possibility was provided by school leader	–	Via the research project	13	3	m	42	Master of Education
2	Subject-specific	One school	4	Weekly	Teaching methods for mathematics	Possibility was provided by school leader	–	Contact of the researchers	27	2	m	51	Master of Arts (Ed)
3	Subject-specific	Different schools	5	Monthly	Teaching methods for physics	Asked by school leader	Professor of university of applied sciences	Contact of the researchers	7	2	m	63	PhD
4	Subject-specific	Different schools	8	Irregular/ unscheduled	Teaching methods	On its own initiative	–	Via the research project	8	2	v	58	Master of Education
5	Subject-specific	Different schools	15	Monthly	Teaching methods for physics	Asked by school leader	University teachers	Via the research project	13	4	m	35	Bachelor of Education
6	Subject-specific	Different schools	6	Less than monthly	Teaching methods for biology	Possibility was provided by school leader	–	Internet search	10	3	v	35	Master of Education
7	cross-curricular	One school	13	Weekly	School organisation	School organisational	External educational coach	Via the research project	7	4	m	39	Master of Education
8	cross-curricular	Different schools	6	Less than monthly	Teaching methods for music	Through a colleague	–	Internet search	17	3	v	45	Bachelor of Education
9	cross-curricular	Different schools	10–15	Less than monthly	School specific identity	On its own initiative	–	Internet search	20	8	v	59	Bachelor of Education
10	cross-curricular	Different schools	20	Monthly	Human rights	On its own initiative	–	Internet search	5	4	m	29	Master of Education
Research-informed													
11	Subject-specific	Different schools	9	Monthly	Pedagogical content knowledge in digital literacy	On its own initiative	Researcher (university)	Via the research project	13	2	m	43	Master of Education
12	Subject-specific	Different schools	12	Less than monthly	Migration in history	On its own initiative	University teacher	Internet search	37	3	v	56	Bachelor of Education
13	Subject-specific	Different schools	5	Monthly	Academic writing skills in language	Asked by school leader	University teacher	Via the research project	10	3	v	n.a.	Master of Education
14	Subject-specific	Different schools	20	Monthly	Migration in history	Asked by school leader	University teacher	Via the research project	n.a.	2	v	n.a.	Master of Education
15	Subject-specific	Different schools	15	Less than monthly	Various economic topics	Asked by the coordinator of the tLG	–	Internet search	13	2	v	52	Master of Education
16	Subject-specific	Different schools	10	Less than monthly	Subject specific theme's, differentiation	Through mailing university	University teacher	Internet search	12	1	v	37	Bachelor of Education
17	cross-curricular	One school	5	Weekly	General pedagogical skills	On its own initiative	–	Contact of the researchers	28	2	m	52	Bachelor of Education
18	cross-curricular	One school	12	Weekly	General pedagogical skills	School organisational	External educational coach	Internet search	14	1	m	39	Master of Education
19	cross-curricular	One school	5	Weekly	Differentiating between students	Possibility was provided by school leader	University Teacher	Via the research project	8	n.a.	v	38	Master of Education
20	cross-curricular	One school	5	weekly	Differentiating between students	Possibility was provided by school leader	Researcher (University)	Via the research project	4	n.a.	v	28	Master of Arts (Ed)
21	cross-curricular	Different schools	5	Monthly	Dynamic modelling in science	On its own initiative	Researcher (university of applied sciences)	Via the research project	23	4	m	41	Master of Arts (Ed)
22	cross-curricular	Different schools	15	Less than monthly	Personalised teaching	On its own initiative	–	Via the research project	15	1	v	42	Master of Education
23	cross-curricular	Different schools	12	Less than monthly	Personalised teaching	Possibility was provided by school leader	–	Via the research project	30	n.a.	m	n.a.	Bachelor of Education
24	cross-curricular	Different schools	25	Monthly	Personalised teaching	Asked by school leader		Via the research project	17	n.a.	m	n.a.	Bachelor of Education

25	cross-curricular	Different schools	12	Less than monthly	Pedagogical implications of new physics exam	On its own initiative	Selected teacher became guider himself Support point from a university of applied sciences	Via the research project	23	8	m	41	Master of Education
26	cross-curricular	Different schools	16	Monthly	Designing practical assignments in physics	On its own initiative	Educational coach from a university of applied	Via the research project	21	3	m	47	Master of Education
27	cross-curricular	Different schools	8	Monthly	General pedagogical skills	Asked by school leader	2 teacher-researchers from participating schools	Via the research project	25	n.a.	m	55	Master of Education
28	cross-curricular	Different schools	15	Weekly	Integration of refugees in education	Asked by school leader	External educational coach	Via the research project	15	2	v	n.a.	Bachelor of Education
29	cross-curricular	Different schools	12	Monthly	Causal and multi-perspective reasoning in human and society subjects	Possibility was provided by school leader	Researcher (university)	Internet search	4	2	v	30	Bachelor of Education
30	cross-curricular	Different schools	8	Monthly	Continuing learning lines in language and arithmetic	Asked by school leader	External educational coach	Internet search	39	6	m	59	Master of Science
31	cross-curricular	Different schools	7	Monthly	Students with giftedness	Asked by school leader	Researchers (2) (university)	Internet search	30	1,5	m	62	Bachelor of Education
Research-based													
32	cross-curricular	One school	6	Every two weeks	Research skills in various themes	Possibility was provided by school leader	Section head school leader	Via the research project	9	n.a.	v	53	Bachelor of Education
33	cross-curricular	One school	4	Monthly	Use of apps in classroom	On its own initiative	University of applied sciences teachers (2)	Internet search	12	2	m	32	Master of Education
34	cross-curricular	One school	5	Weekly	Language-focused subject-matter teaching	Asked by school leader	Researcher (university)	Contact of the researchers	14	3	v	34	Master of Education
35	cross-curricular	Different schools	9	Weekly	Differentiating between students	Asked by school leader	Researcher (university)	Via the research project	3	2	m	25	Bachelor of Education
36	cross-curricular	Different schools	6	Monthly	Differentiating between students	Through a colleague	Researchers (2) (university)	Contact of the researchers	10	2	v	57	PhD
37	cross-curricular	Different schools	35	Two weekly	Continuous student progression; Differentiating between students	On its own initiative	University teacher	Contact of the researchers	5	3	m	48	Master of Education
38	cross-curricular	Different schools	20	Less than monthly	Continuous student progression	Asked by school leader	Researcher (university)	Internet search	20	3	v	56	Master of Science
39	cross-curricular	Different schools	8	Monthly	Continuous student progression	Asked by school leader	Researchers (2) (university)	Internet search	37	3	m	61	Master of Education

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tate.2019.04.019.

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