Characteristics of Professional Learning Communities in Mathematics: A Systematic Review

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Professional Learning Communities (PLC) have been used increasingly in designing and discussing teachers' professional development, but how PLC are organised and framed differ between contexts. There is a lack of meta-level studies that aim to define and compare different ways of organising PLC. In this literature review of 32 studies, Cultural-historical Activity Theory (CHAT) is used as an analytical lens to examine different models for PLC in mathematics. By examining and comparing PLC in mathematics, the review aims to expand understanding of how PLC in mathematics can be organised and framed. The result revealed three distinctive activity systems with different objects: developing norms for collaboration, developing teachers' understanding about mathematics and its teaching, and developing teachers' repertoire of teaching actions. The activity systems vary concerning the use of mediating artifacts and the norms that regulate each activity system, but are similar regarding participants, context, and division of labor. The review indicates that the teachers participating in PLC in mathematics change their norms of collaboration, enhance their understanding of mathematics and its teaching, and/or enhance their ability to design and carry out mathematics teaching. Our findings can assist designers, organisers, participants, and researchers in making informed decisions about PLC in mathematics.

Keywords · teacher professional development · professional learning communities · systematic review · activity theory· student work · mathematics

Introduction

The competence of teachers is an important factor in students' educational progress (Hattie, 2009), as is the development of teaching practices (Katz & Ain Dack, 2012). As a consequence of this the professional development of teachers is high on the policy agenda in many countries (Erixon & Wahlström, 2016) and most teachers in Organisation for Economic Co-operation and Development (OECD) countries participate in some form of professional development during their career (OECD, 2016). Vast amounts of money and effort are invested in teachers' professional development it reasonable to discuss the design and content of these endeavours. In recent decades, research has shown that teacher professional development, rather than being organised as individual short-term events, should last for an extended time and include joint participation to develop teaching (see e.g., Desimone, 2009; Guskey, 2002; Heck et al., 2008). There are several ways of organising such joint work, for example, formal teacher communities, member-oriented teacher communities and formative communities (Vangrieken et al., 2017). These include many different activities and purposes. Not all the approaches, however, seem to be successful in developing teaching practices. Joint participation alone simply does not seem to be enough to develop teaching development (Robutti et al., 2016). Therefore, there is a need to investigate how

teachers' joint work can be organised and framed in order to promote professional development, which results in the development of teaching practice.

Research on effective teacher professional development highlights the importance of teacher collaboration, where teachers are not just working side by side, but rather collaborating to develop new ideas and to promote school change beyond their individual classrooms (Darling-Hammond et al., 2017; Hord, 1997; Knapp, 2017; Louis et al., 1996; Perez et al., 2007). For teaching to improve, such collaboration requires a systematic inquiry into one's practice. This way of inquiring into one's own teaching can be contrasted to the more common discussions and exchanges of experiences that teachers regularly take part in and which are general in nature (Garrison, 2016; Jaworski, 2006; Ryve et al., 2016; Swedish National Agency for Education, 2017).

There are several ways of conceptualising teachers' joint work aiming to develop the teaching practice (Levine, 2010). *Collaborative, collegial, collective,* and *communities,* are commonly used terms in previous literature to capture the collective aspect of the work (e.g., Garrison, 2016; Makopoulou & Armour, 2014; Robutti et al., 2016; Vangrieken et al., 2017). Various cultural connotations, however, contribute to difficulties in pinpointing to what the concepts refer and, therefore, what they entail. In this study, we have chosen *Professional Learning Communities (PLC)* to refer to teachers' systematically organised collaborative work that aims to inquire critically into and develop teaching practice.

PLC are commonly used in an educational setting to conceptualise collaborative teacher work (Vangrieken et al., 2017). There is, however, no universal definition of PLC and the interpretation of what PLC entail, and how they are framed and organised seem to differ between contexts (Stoll et al., 2006). This complicates research on, as well as evaluation of, PLC as a form of teacher professional development since it can prove difficult to identify which of the elements of PLC that are fruitful. It also makes it more challenging for teachers to develop experiences of how to work collectively that are valid across contexts. Even though there is no universal definition of PLC, there are some common characteristics (Stoll et al., 2006). PLC are constituted by the "school staff team, which works collaboratively and collegially in order to improve student learning" (Vangrieken et al., 2017, p. 49), by "sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive and learning-oriented, growth-promoting way" (Stoll et al., 2006, p. 223). The interpretation of what activities PLC entail and how they are framed and organised however, seem to differ between contexts. The improvement of teaching can for instance be related to general pedagogical issues, when teachers are working together with teaching issues that are not focused on a specific school subject (e.g., Langelotz, 2017), as well as specific pedagogical issues centered on a subject such as mathematics (e.g., Jaworski, 2006). They may include varying numbers of participants from the same or different schools, consisting of different or the same category of school staff. The organisation of the inquiry may differ as well (Vangrieken et al., 2017).

Research studies often report on specific PLC in mathematics, but there is a lack of meta-level studies that aim to define and compare the different ways of organising PLC (Krainer & Spreitzer, 2020). In this study we focus on PLC in mathematics, in which mathematics teachers collaborate to improve their teaching practice. The study contributes a synthesis of previous research to provide an overview of how PLC in mathematics can be organised and framed. With PLC, we refer not only to the individuals of whom the group consists, but also to its activities. A common activity is a learning session, which is a physical meeting, at a certain time and place, where collaborative work is carried out.

Research questions

The purpose of this study was to contribute to the understanding of how PLC can be organised and framed. Through a systematic review of research on PLC in mathematics, we aimed to provide an overview of how these can be organised and framed and examined different ways in which PLC in mathematics play out in practice. In doing so, we hoped to clarify meanings attached to PLC in mathematics. Knowledge about different ways of organising PLC may help uncover problematic issues. By highlighting the conflicting ideas on issues such as the aims of PLC, or how to approach content, our study can assist designers, organisers, participants, and researchers, in making informed decisions about PLC in mathematics. The following research questions have guided this study:

- How are the professional learning communities in mathematics organised and framed in previous research?
- What similarities and differences are visible among different professional learning communities in mathematics?

To answer the research questions, we conducted a systematic literature review. Our review was a configurative research review aimed at interpreting and understanding empirical data (Gough et al., 2012). To investigate and conceptualise the complex phenomenon of PLC, we used Cultural-historical Activity Theory (CHAT) (Engeström, 1987). We use activity systems, one of the key concepts of CHAT, to investigate PLC. In the next section the basic principles of activity systems are described.

Cultural-historical Activity Theory and Activity Systems

CHAT is a practice-based theory used to analyse professional work practices. In the analysis such practices are conceptualised as activity systems, in which people with different roles and perspectives interact and carry out actions aimed to develop their practice (Engeström, 1987; Foot, 2014). In CHAT, activity systems are taken as the smallest unit of analysis (Engeström, 1987) and are often illustrated through a triangle (Figure 1). One of the strengths of conducting analyses of activity systems is the potential to capture the complexity of work practices (Foot, 2014). Complex practices such as teaching have, in the educational research field, increasingly been examined through *activity system analysis* (Gedera & Williams, 2016; Yamagata-Lynch, 2010).

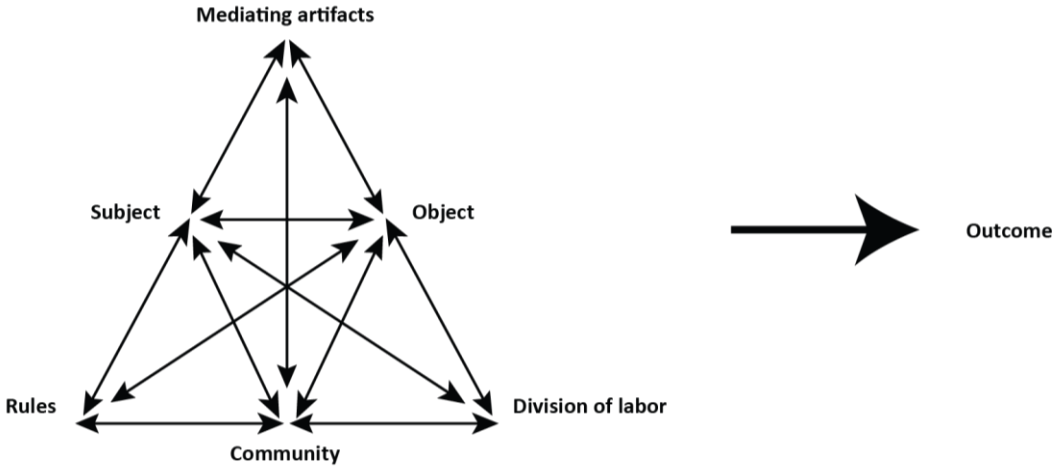

Figure 1. An activity system, as illustrated by Engeström (1987, p. 78)

An activity system consists of six nodes and an outcome. The *object* is the underlying "true" motive for the activity. It can be argued that the object determines what can be considered an activity system. If the object changes, then a new activity system has been created. Several activity systems can be active concurrently and participants can move between them (Foot, 2014). The object for participation in PLC may be, for example, changed practice, increased student learning, increased salary, or qualifications. The object of a system is an empirical question in the sense that it is not always explicit (Öhman Sandberg, 2014). The *subjects* are the participants who share the object of activity. They can be for example teachers who want to improve their teaching.

Mediating artifacts are the tools with which the object is achieved. A tool can be for example a video clip from the classroom, a set of questions, a protocol, or an instruction for observing classroom teaching. The *rules* describe the explicit and implicit rules and norms, which are shared by the participants in the activity. An example of a norm is the expectation that every teacher should be prepared to share video clips from their teaching. *Community* refers to the significant others, the people who share an interest in the same object as the subject, but who are not directly involved; an example of this can be colleagues who are not part of the specific PLC in question. *Division of labor* describes both the expressed roles of the subjects and implicit hierarchical structures. Leading a PLC is an example of such a role. To every activity system, there is also an *outcome*, which can be defined as the change and/or result of an activity (Definitions are a synthesis of Engeström, 1987, 1999). The arrows within Figure 1 represent actions within an organisation, and the system can be viewed as the context in which actions and processes occur (Hirsh & Segolsson, 2019, p. 3).

With inspiration from Engeström (1999), we have conceptualised PLC as activity systems. These practices are then taken as units of analysis, and the six nodes are used as overall categories to understand and organise the practice (Yamagata-Lynch, 2010). Since the descriptions of the six nodes are general, researchers have worked in different ways to find ways to understand their respective phenomena as activity systems. Mwanza (2002) developed a set of questions that has

the potential to be used to specify how the content of each node could assist an activity system analysis. Mwanza's questions can be found in the "Eight-Step-Model", which is presented in Table 1. In the next section we present the method of this systematic literature review.

Table 1
Eight-Step-Model (Mwanza, 2002)

Activity system component	Question to ask
Activity	In what sort of activity am I interested?
Objective	Why is this activity taking place?
Subjects	Who is involved in carrying out the activity?
Tools	By what means are the subjects carrying out this activity?
Rules and regulation	Are there any cultural norms, rules, and/or regulations governing the performance of this activity?
Division of labor	Who is responsible for what, when carrying out this activity, and how are the roles organised?
Community	What is the environment in which the activity is carried out?
Outcome	What is the outcome of this activity?

Note. Mwanza (2002) used the terms component instead of node, tools instead of mediating artifacts and objective instead of object. In this article, we have used Engeström's (1987) original terms.

Method

Previous research on professional development endeavoured using PLC demonstrates a variety of ways to organise, frame and conceptualise the PLC. Research studies often reported on specific PLC in mathematics, but such studies lack a meta-level that offers opportunities to define and compare different ways of organising PLC. To describe the ways PLC in mathematics are, or can be, organised, we have chosen to do a systematic review. The overarching purpose of systematic reviews is to use explicit and accountable methods to bring together what is known from the research literature (Gough et al., 2012). Given that research studies vary regarding research questions, methods for analysis, theoretical perspectives, and underlying assumptions it is to be expected that systematic reviews of qualitative research will vary in similar ways. In education research, which is varied in terms of methods and theoretical perspectives, it is often difficult to aggregate findings, and alternative methods have been suggested. Reviews aimed at interpreting and understanding empirical data are *configuring* information and can therefore be termed configurative reviews. While aggregative research tends to look for evidence needed to inform decisions, configuring research investigates concepts to provide new ways of understanding a complex phenomenon (Gough et al., 2012). Our study is a configurative research review in which we, by interpreting and understanding empirical data, examine PLC in mathematics.

Identifying relevant research studies

The review procedure consisted of two phases, a first phase in which research studies were identified, and a second phase where the studies were analysed and synthesised. To identify

empirical studies on PLC in mathematics, we turned to ERIC[1] and Web of Science[2]. By reading abstracts from studies, that were identified early on relevant keywords connected to PLC were identified. After this process, the following terms were used in the final systematic search: ((professional learn*) OR (professional development)) AND ((collegial OR collective OR collaborative OR communit* OR group*) AND learn*) AND math* AND teach*.[3] To be contemporaneous we restricted the review to articles published after 2008. The searches were performed on May 16, 2018 and resulted in 918 original research reports.

Manual selection process

A manual selection process was carried out to exclude studies which were not empirical and did not focus clearly on the PLC in mathematics among teachers in compulsory schooling. The inclusion criteria were:

- The study is about teachers in mathematics and includes three or more teachers (studies which, partly or wholly, include teachers of other subjects were excluded, as were studies including pairs of teachers or one teacher and one researcher).
- The study is about teachers' joint work (studies with a focus on students' joint work or the development of a single teacher's work were excluded).
- The study is about PLC with physical meetings over an extended time (online-courses were excluded, as were PLC including a few singular learning sessions).
- The PLC in the study were not part of any regular post-graduate course.
- The study is empirical (literature reviews were excluded).
- The teachers in the study are in-service teachers in primary, elementary, or secondary level.

Through this manual process, 886 studies were excluded. The remaining 32 studies comprise the data for the review (Appendix A).

Analysis

The PLC constitute our primary unit of analysis. The analytic process was conducted in two phases. In the first phase we aimed to answer our first research question: *How are the professional learning communities in mathematics organised and framed in previous research?* and in the second phase we sought to answer the second research question: *What similarities and differences are visible between different professional learning communities in mathematics*?

In the first phase, the focus was on organising and categorising the results of the 32 studies in the six nodes, and the outcome of the activity system, using and asking the questions included in the eight-step model (Mwanza, 2002) (Table 1). All 32 studies were read by each of the researchers, who individually categorised the results of the studies into the six nodes, followed by

[1] Database which includes research on pedagogy, education, and learning.
[2] Database consisting of several international citation indexes.
[3] Asterisks are used to include different endings on the keywords, for example, the use of communit* enables inclusion of both commun*ity* and communit*ies* in the result.

a joint discussion between the researchers, who then went back to the articles to deepen, confirm, or adjust their understanding of the content of the nodes.

In the second phase, the aim was to identify similarities and differences in how PLC are organised. We compared the studies regarding each node, using the results of the analysis in the first phase. The three nodes, in which we identified the most prominent differences between the studies, were *object*, *mediating artifacts,* and *rules*. Outside of the six nodes the outcomes of the PLC also differed. Three distinctly different objects were identified and based on these three we constructed three different activity systems. We examined which mediating artifacts and rules were characteristic of each activity system. In the following section we present the results of the analysis in relation to the two phases detailed above.

Result of Phase 1: Categorisation into the six nodes and outcome

Object: Why is this activity taking place?

There are primarily three different objects for the PLC in mathematics. The first object is to develop norms for collaboration in the PLC. When this is the object, it seems as if mathematics teaching serves as means to an end, the end being the development of norms that allow teachers to collaborate in productive ways, something that they are unaccustomed to. The second object that is visible in some studies is developing the teachers' understanding of mathematics and its teaching. The third and final object is developing the teachers' repertoire of teaching actions. The second and third object represent PLC in which mathematics teaching is the goal and the norms that allow for collaboration among teachers is the means.

Object A: Developing norms for collaboration

We identified studies in which the main object of the PLC was to learn how to use a model for joint work; this goal was often linked to contexts where it is uncommon for teachers to collaborate. Four articles (see Appendix B) described the way the teachers engaged in the PLC as such, rather than the outcome of the PLC in terms of an improved teaching or improved learning outcomes for students. Studies from Iran (Moghaddam et al., 2015) and China (Lim et al., 2016) are examples of studies that highlighted the importance of the cultural background of the participating teachers. The teachers in these studies were from a culture that puts an emphasis on independence, rather than collaboration, and where teachers tend to work individually, rather than in groups. Elements of the Japanese model for lesson study, such as "a culture of openness, collaboration, and self-reflection" (Moghaddam et al., 2015, p. 171), were foreign to the teachers, and prior to the projects described in the articles they were unaccustomed to working together to reflect on their teaching. In such situations, it is essential to view the fostering of collaborative norms as a major object. In contrast, most studies in a Western or Japanese context did not report on cultural obstacles to teacher collaboration. When the fundamental norms for collaboration were already established, the object was rather to implement or examine specific ways in which to collaborate. In the study by Borko et al. (2008) the focus was on the nature of the teachers' interactions in discussing classroom activities, whereas the study by Dobie and Anderson (2015)

described an even more fine grained analysis by investigating the way teachers contradicted each other in discussions.

Object B: Developing teachers' understandings about mathematics and its teaching

Fifteen studies described PLC which aimed to develop teachers' understandings of the prerequisites for developing mathematics teaching. These studies (see Appendix B) described PLC whose object was to equip teachers with knowledge of the concepts, research findings, and mathematical skills so that they could use these in discussions on how to improve their teaching. Examples of such concepts were *formative assessment* (Wylie et al., 2008) and *mathematical reasoning* (Lesseig, 2015). Examples of research findings used in discussions included articles on the teacher role in good mathematics teaching (Gellert, 2013; Hauge & Norenes, 2009), and articles about learning errors connected to a mathematical concept (Brodie & Shalem, 2011).

In nine out of the 15 studies developing this understanding dominated the early part of the PLC. Development of the actual teaching practice then occurred in the later stages of the PLC (Borko et al., 2008; Brodie, 2013; Brodie & Shalem, 2011; Gee & Whaley, 2016; Gibbons et al., 2017; González et al., 2016; Lesseig, 2015; Wylie et al., 2008).

Object C: Developing teachers' repertoire of teaching actions

Developing teaching practice by focusing on teachers' repertoire of teaching actions was the most common object of the PLC (Appendix B). Twenty-seven studies described PLC where teachers worked to develop their teaching actions by implementing new teaching strategies, changing and refining teaching strategies that were already in use, or developing the teachers' ability to discern and identify what it is that students are doing when they are learning mathematics. The content of the learning sessions consisted of general, as well as math-specific issues. Moghaddam et al. (2015) and Goodnough and Murphy (2017) described projects in which teachers analysed mathematics lessons, but where the focus of the analysis was on general aspects rather than aspects specific for teaching mathematics. In these cases mathematics acted as the means to develop general knowledge about how teaching can be organised. Other projects were mathematics specific. For example, the Professional Learning Community described by Cajkler et al. (2014) aimed to improve the teaching on the subtraction of multiple digit numbers. The Professional Learning Community described by Won (2017) aimed to develop strategies for improving students' mathematical critiquing and argumentation.

Several parallel objects in the same PLC

It is important to note that few studies reported a single object for the PLC. Instead, it was common to state several parallel objects even if they were distinctly different. Examples are studies in which the PLC is used as an object and a means concurrently (see e.g., Borko et al., 2008), i.e., the PLC explicitly meant to develop a culture in which the PLC is used as a long-term tool and to develop the teachers' understanding of teaching and their repertoire of teaching actions. Developing and establishing norms for collaboration was described as something that is necessary before developing either the teachers' understanding of mathematics and teaching, or their teaching actions. In teacher groups where norms that allow for teachers to collaborate were not previously familiar to the participants, for example, for the teacher groups described by Lim et al. (2016) and

Moghaddam et al., (2015,) this was especially important. The object of developing norms for collaboration thus precedes other objects.

Subject(s): Who is involved in carrying out the activity?

The subjects in all the studies were mathematics teachers. In other words, mathematics teachers were involved in carrying out the activities in all the studies. Teacher leaders were also recognised as an essential part of the organisation of most of the PLC in mathematics. Subcategories such as headteachers and principals were also sometimes included (e.g., Hauge & Norenes, 2009; Lesseig, 2015; Slavit et al., 2011). Other subjects who took an active role in the PLC were the researchers themselves, most often acting as teacher leaders as well as initiators of and designers of the PLC (Gellert, 2013; Gibbons et al., 2017; Hauge & Norenes, 2009; Lesseig, 2015; Moghaddam et al., 2015; Murata et al., 2012; Slavit et al., 2011; Takahashi & McDougal, 2016; Widjaja et al., 2017). Among the studies, it varied whether the participating mathematics teachers come from the same school or different schools. The most common constellation was a group of three to five teachers who taught mathematics to students of the same age and came from the same school. There were instances in which the participation in the PLC was mandatory, and this category primarily included teachers from the same school (e.g., Gibbons, 2017). In other instances, the participation was voluntary, and, in such cases, it was most common for the teachers to come from different schools (e.g., Horn & Kane, 2015). In several of the studies, the participants were awarded financial compensation, or some type of higher education credit, for their participation. Issues regarding the constellation of participants in a PLC, whether the participation was mandatory or voluntary, and if, and in what way, participants already were familiar with each other, were seldom described or problematised.

Mediating artifacts: By what means are the subjects carrying out this activity?

All the studies described frameworks that were used to carry out activities at an infrastructural level. Those frameworks offered structures that organised the subjects' work and supported implementation systematicity over an extended period. The most common frameworks were lesson studies and video clubs.

Besides the infrastructural frameworks there were also mediating artifacts that worked on a more operative level in the learning sessions. These mediating artifacts were used by the subjects to generate discussions and collective analysis and they included, among others, video clips, classroom data, and mathematical problems. The artifacts differed in relation to the different objects: *developing norms for collaboration (Object A*), *developing teachers' understandings about mathematics and its teaching (Object B)*, and *teachers' repertoire of actions (Object C)*, meaning that the artifacts used were selected depending on the object. One type of artifact, for example video clips, can be used to develop more than one object, something that was evident in several studies (e.g., Borko et al., 2008; Gellert, 2013; Hauge & Norenes, 2009; Lim et al.,2016). It was common that several mediating artifacts are used in combination.

Mediating artifacts for Object A: To develop norms for collaboration

When the object was to develop norms for collaboration, mediating artifacts were used to create safety and trust among participants, enable and support active participation, critical inquiry, and reflection, and to direct teachers' attention towards relevant issues (Table 2).

Table 2
Mediating artifacts used to develop collaborative norms

Mediating artifact	Found in the following studies
Video clips of PLC work.	Borko et al., 2008; Lim et al., 2016
Structured questions designed to encourage the sharing of ideas and reflections.	Borko et al., 2008; Dobie & Anderson, 2015; Lesseig, 2015; Lim et al., 2016
Strategies to incorporate important aspects from previous learning sessions.	Lesseig, 2015

The video clips used to develop Object A highlighted the different ways teachers' work has been organised in previous PLC (Lim et al., 2016). These video clips were thus different from the clips used in developing the other objects, where teaching situations and student interactions were analysed.

The teacher leader played an important role in establishing new norms. First, by acting in accordance with the new and desired norms, thus acting as a role model. Second, by preparing and presenting structured questions to encourage teachers to share their thoughts, reflect on issues, and to focus on the mathematics (Borko et al., 2008; Dobie & Anderson, 2015; Lesseig, 2015; Lim et al., 2016).

Mediating artifacts for Object B: To develop teachers' understandings about mathematics and its teaching

When the object was to develop teachers' understandings about mathematics and its teaching, mediating artifacts were used to highlight different mathematical concepts and strategies or concepts from mathematics education (Table 3).

Table 3
Mediating artifacts used to develop teachers' understanding of mathematics and its teaching

Mediating artifact	Found in the following studies
Video clips from teaching situations.	Borko et al., 2008; Gellert, 2013; Hauge & Norenes, 2009
Rich mathematical problems, which the teachers solve and/or where students' solutions are discussed.	Borko et al., 2008; Campbell & Stohl Lee, 2017; Gibbons et al., 2017; Won, 2017
Structured and challenging questions focusing on mathematical concepts.	Lesseig, 2015
Curricular documents and teaching materials.	Brodie, 2013; Brodie & Shalem, 2011; Gellert, 2013
Research articles and books.	Brodie & Shalem, 2011; Gibbons et al., 2017; Goodnough & Murphy, 2017; Lesseig, 2015

Video clips, research articles, and books in this category were used to initiate discussions about the meaning of mathematical concepts or concepts from mathematics education. Rich mathematical problems were used to enhance teachers' knowledge about specific mathematical contents, strengthen their own problem-solving competence, and expand their understanding of different problem-solving strategies. Teachers solved rich mathematical problems together; this process offered them an opportunity to discuss their understanding of the mathematical content and different problem-solving strategies (Borko et al., 2008; Campbell & Stohl Lee, 2017; Gibbons et al., 2017).

Curricular documents, teaching materials, research articles, and books, were used as preparation for learning sessions. Teachers had an opportunity before the learning session to review various material which could help them deepen discussions during the learning session (Brodie, 2013; Brodie & Shalem, 2011; Gellert, 2013; Gibbons et al., 2017; Goodnough & Murphy, 2017; Lesseig, 2015).

Mediating artifacts for Object C: to develop teachers' repertoire of teaching actions

When the object was to develop teachers' repertoire of teaching actions mediating artifacts were used to highlight different aspects of mathematics teaching (Table 4). For example, designing lesson plans involved formulating learning objectives, creating tasks and material, planning for productive interaction between teachers and students, and anticipating and discussing students' reasoning. Video clips and observations were used to understand students' mathematical reasoning and to analyse and evaluate teaching that had been planned in collaboration. The focus of the video clips were, in some studies, the teacher's actions and, in other studies, the students' actions. Borko et al. (2008) and Van Es (2009) suggest that the latter is more common.

Brantlinger et al. (2011) pointed out that the use of video clips from the classrooms of the participating teachers can be a delicate practice since teachers may feel uncomfortable accepting and delivering critical reflections from and to their peers, even if this ability seems to develop with time. Lesseig (2015) and Wake et al. (2016) suggested that observation protocols, or frameworks, facilitate analysis of teaching (Lesseig, 2015; Wake et al., 2016).

Student data were, in several cases, used to identify issues in need of development, but also to evaluate teaching or to identify students' misunderstandings or difficulties. The findings of Slavit et al. (2011) indicated that even though the material collected from teachers' teaching practice acted as an important base for analysis and discussions in PLC, it is still a challenging task for participants to examine such data. Teachers are unaccustomed to analysing data from classrooms (Slavit et al., 2011) and need time to develop this ability (Borko et al., 2008; Slavit et al., 2011; Won, 2017).

Table 4
Mediating artifacts used to develop teachers' repertoire of teaching strategies.

Mediating artifact	Found in the following studies
Lesson plans.	Borko et al., 2008; Brodie, 2013; Brodie & Shalem, 2011; Cajkler et al., 2014; Campbell & Stohl Lee, 2017; Gee & Whaley, 2016; Gibbons et al., 2017; Goodnough & Murphy, 2017; Lesseig, 2015; Lim et al., 2016; Moghaddam et al., 2015; Murata et al., 2012; Ni Shuilleabhain & Seery, 2018; Wake et al., 2016; Warwick et al., 2016; Won, 2017
Video clips from teaching situations, authentic or animated.	Borko et al., 2008; Brantlinger et al., 2011; Gamoran Sherin & van Es, 2009; Gellert, 2013; González et al., 2016; Hauge & Norenes, 2009; Van Es, 2009
Observations of mathematics lessons.	Cajkler et al., 2014; Gee & Whaley, 2016; Goodnough & Murphy, 2017; Hunter & Back, 2014; Lesseig, 2015; Lim et al., 2016; Moghaddam et al., 2015; Murata et al., 2012; Warwick et al., 2016
Student data for example solutions, interviews, pre- and post-tests, grades, and surveys.	Brodie, 2013; Brodie & Shalem, 2011; Goodnough & Murphy, 2017; Lesseig, 2015; Murata et al., 2012; Slavit et al., 2011; Taylor, 2012; Warwick et al., 2016
Structured and challenging questions focusing on different aspects of the teaching.	Borko et al., 2008; Dobie & Anderson, 2015; Lesseig, 2015; Lim et al., 2016

Rules: Are there any cultural norms, rules, and/or regulations governing the performance of this activity?

The studies described norms that existed prior to the PLC and norms that developed during the PLC. None of the studies reported on explicit rules or regulations that guided the activities, which is why we under this heading have focused on norms alone. Two different sets of descriptions of norms were identified in the studies. In the first set we found studies that described schools in which norms that allow teachers to collaborate were already established, and teachers were accustomed to working together when planning or evaluating teaching. In the second set such

norms were not established; the schools featured in these studies were described as schools where independence, rather than collaboration, is expected, and where teachers tended to work individually rather than in groups. In the latter group of studies, the development of norms that allowed teachers to collaborate was seen as a major object of the PLC.

In the first set of studies where norms that allow collaboration were already established, certain norms were described as more productive than others in supporting the teachers' work. These norms can be understood as belonging to three categories; *norms that support teachers' active participation, reflection, and critical inquiry, norms that support open communication and a sense of trust*, and *norms that direct teachers' attention towards an object*.

The norms in the second category acted as prerequisites for the first category. Critical inquiry and reflection require trust and an openness to new ideas. Examples of norms in the first category were expectations that teachers would be willing and be prepared to share experiences and video material with peers (Brantlinger et al., 2011; Lesseig, 2015; Won, 2017). Other norms included the shared belief that teachers could learn from collective critical inquiry by putting forward and examining different perspectives (Brodie, 2013; Ni Shuilleabhain & Seery, 2018). In the second category were norms concerning behavior that helped create trust among the participants. They were expected to support and encourage each other by listening to others' arguments and to use them as a base from which to build new knowledge (Dobie & Anderson, 2015; Van Es, 2009; Won, 2017). The critical element needed to be directed towards the development of new practices rather than toward other teachers (Brantlinger et al., 2011; Brodie & Shalem, 2011). The last category contains norms that ensured that the learning sessions were concerned with material, questions, and discussions that were perceived as relevant to the teachers (Hauge & Norenes, 2009; Lesseig, 2015; Slavit et al., 2011). It was important that the teachers had the sense that what they were dealing with were factors in teaching that they could actually control (Gellert, 2013).

In the studies described in this article the norms described above were raised as essential, but challenging, to establish in PLC. Several studies concluded that productive norms develop over time (Borko et al., 2008; Brantlinger et al., 2011; Gee & Whaley, 2016; Hauge & Norenes, 2009; Lesseig, 2015; Slavit et al., 2011). Even in studies that did not draw this conclusion, there are descriptions of changes in teachers' behavior that appear to have taken place over time, suggesting that time is a crucial factor in the establishing of productive norms.

Division of labor: Who is responsible for what, when carrying out this activity, and how are the roles organised?

Teachers were responsible for contributing with knowledge from their teaching practice, sharing their experiences, and were required to be active in examining teaching to build new knowledge. A teacher leader was recognised as an essential part of the organisation in all the studies in the review. Teacher leaders' responsibilities included planning and guiding the work, keeping the focus, deepening the discussion, and establishing norms that facilitate productive discussions on teaching issues. Takahashi and McDougal (2016) studied PLC in which there was a teacher leader and PLC with no appointed leader. The latter groups were less productive than the former. In most of the studies, the PLC were led by external teacher leaders, often by researchers but sometimes by professional supervisors. There were, however, five studies in which the PLC was led by a teacher who was an original member of the teacher group taking part in the PLC (Campbell &

Stohl Lee, 2017; Dobie & Anderson, 2015; Gibbons et al., 2017; Takahashi & McDougal, 2016; Wake et al., 2016). Campbell and Stohl Lee (2017) suggest that there are many reasons why serving as a teacher leader for colleagues can be a challenging task. One of the most prominent reasons is, perhaps, that most teachers lack adequate knowledge of, and experience in, supervising their peers.

In most of the studies researchers were responsible for initiating and designing the PLC, for example by presenting a framework for the overall structure of the PLC. Principals were responsible for creating and sustaining opportunities for teachers to participate in the PLC by ensuring that they have time to attend and take an active part in the learning sessions.

Community: What is the environment in which the activity is carried out?

In the PLC described in the studies, environment was seen as the setting that surrounded the professional development. In most of the studies the PLC were separate from other professional development endeavours, and they took place separate from other activities involving teacher colleagues. There were no descriptions of collaboration between the teachers, who were part of a PLC, and their colleagues, who were not. Some PLC were part of development projects on school, district or regional levels, but there were no descriptions of how teachers who were part of the PLC acted as resources in other reform efforts. Most of the PLC were isolated projects with little or no relation to other professional development or teaching development projects. There is a lack of description of how PLC were sustained and how they progressed after the researchers concluded their interventions. None of the studies report on the ways in which the PLC were sustainable over time, implemented as part of the local school culture, or concluded and replaced by other types of professional development initiatives.

Result of Phase 2: Similarities and differences between PLC

When analysing PLC (or any other endeavour) using CHAT, it is central to identify the object of an activity system since the object determines and differentiates one activity system from another (Foot, 2014). We have identified three objects, Object A: *Developing norms for collaboration*, Object B: *Developing teachers' understanding about mathematics and its teaching* and Object C: *Developing teachers' repertoire of teaching actions*. The first object deals with the development of the activity system in which the work is being done. The second and third objects aim to develop activity systems that are separate from the one in which the work is done (for example the classroom). We have taken these differences to mean that the three objects constitute three different activity systems, A, B and C (Figure 2, 3 and 4).

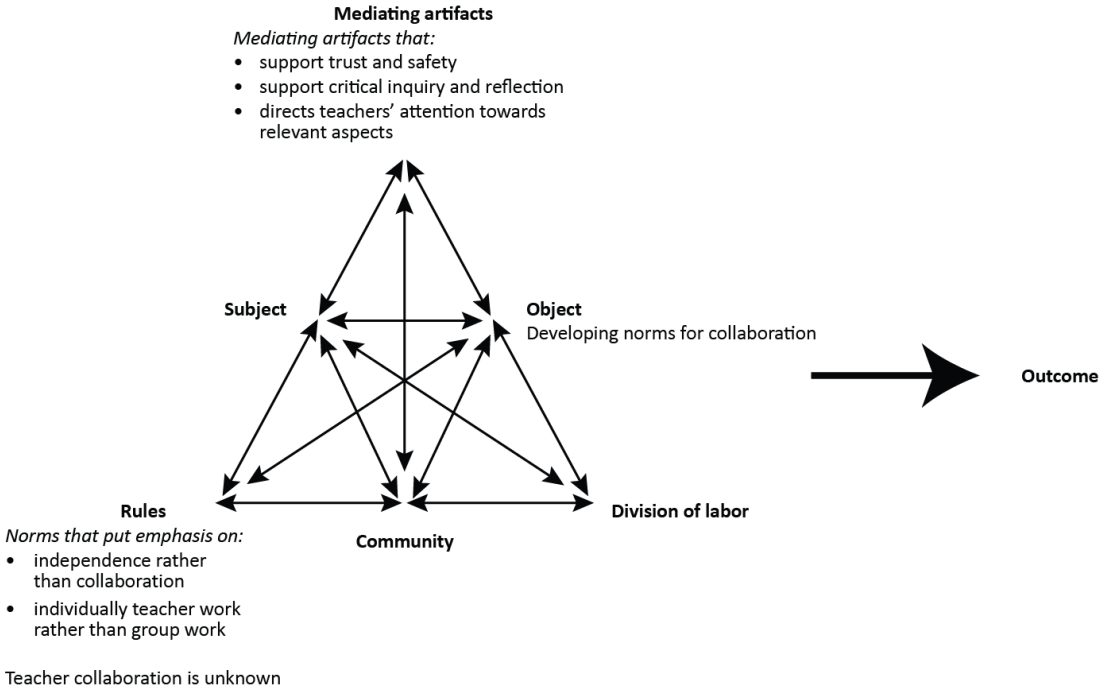

Figure 2. Activity system A.

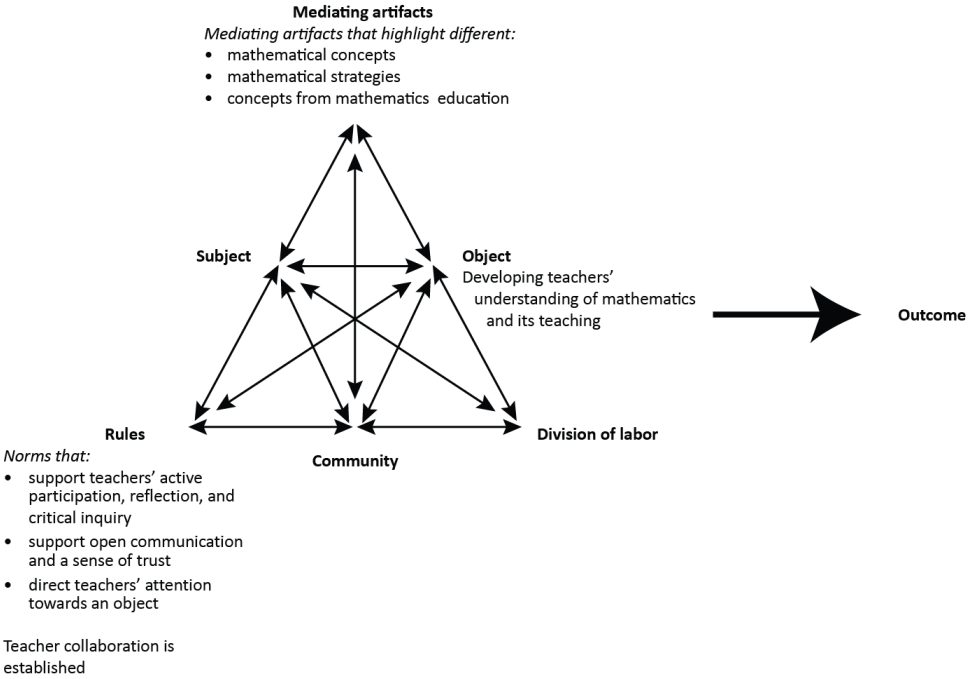

Figure 3. Activity system B.

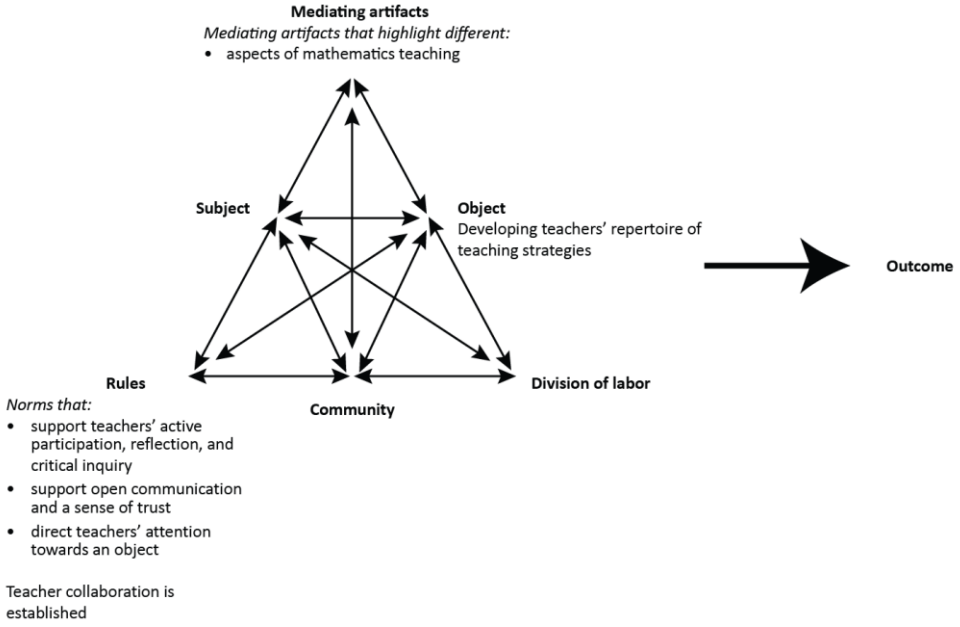

Figure 4. Activity system C

The results shows that different objects have consequences for how the PLC are organised regarding mediating artifacts and norms. The objects determine which mediating artifacts are used in each system. The mediating artifacts are thus used for different purposes in different systems. Mathematical problems are examples of mediating artifacts that are used to create deep mathematical discussions, when these are aimed at developing teachers' understanding of a specific mathematical content (see e.g., Gibbons et al., 2017; Won, 2017). Video sequences of students working with problems are instead used to highlight students' understanding of a specific mathematical content (see e.g., Brantlinger et al., 2011; Van Es, 2009).

The rules and the norms of the activity also correlate with the object of the activity, creating further differences between the systems. The norms are connected to the mediating artifacts used in each system. Discussions on videotaped lessons or teaching sequences are, for example, dependent on norms that require teachers to share their teaching with their colleagues and norms that allow for critical inquiry of this teaching (Brantlinger et al., 2011; Lesseig, 2015; Won, 2017).

The remaining aspects: subjects, division of labor, and community, stay consistent across the three systems. Given that all the studies are concerned with mathematics teachers, and given that school systems, across the western world are relatively homogenous, similarities regarding the participants and their contexts are perhaps to be expected. The identified differences are summarised in Table 5. In the next section we describe the reported outcomes of the PLC.

Table 5
Summary of differences between PLC

Eight step model	Activity system A	Activity system B	Activity system C
Objective Why is this activity taking place?	Object A: Developing norms for collaboration	Object B: Developing teachers' understanding of mathematics and its teaching	Object C: Develop teachers' repertoire of teaching strategies
Tools By what means are the subjects carrying out this activity?	Mediating artifacts to develop Object A Mediating artifacts that: • support trust and safety • support critical inquiry and reflection • directs teachers' attention towards relevant aspects	Mediating artifacts to develop Object B Mediating artifacts that highlight different: • mathematical concepts • mathematical strategies • concepts from mathematics education	Mediating artifacts to develop Object C Mediating artifacts that highlight different: • aspects of mathematics teaching
Rules and regulation Are there any cultural norms, rules, and/or regulations governing the performance of this activity?	Teacher collaboration is unknown Norms that put emphasis on: • independence rather than collaboration • individually teacher work rather than group work	Teacher collaboration is established Norms that: • support teachers' active participation, reflection, and critical inquiry • support open communication and a sense of trust • direct teachers' attention towards an object	Teacher collaboration is established Norms that: • support teachers' active participation, reflection, and critical inquiry • support open communication and a sense of trust • direct teachers' attention towards an object

Note. Only nodes, where differences were found, are included in the table.

Outcomes: What is the outcome of this activity?

The studies presented a variation of outcomes of participation in PLC in mathematics. We identified three different categories of outcomes: *changed norms for collaboration*, *enhanced understanding of mathematics and its teaching*, and *enhanced ability to design and carry out mathematics teaching*. It can be noted that the stated object of a professional learning community does not always correspond with the outcome. There were only three studies in which there was a complete correspondence between object and outcome (Borko et al., 2008; Campbell & Stohl Lee, 2017; Horn & Kane, 2015) where, for example, the object "developing teachers" repertoire of teaching strategies corresponds with the outcome "enhanced ability to design and carry out mathematics teaching." The three identified activity systems A, B and C (Figures 2, 3 & 4) were thus not associated with a particular outcome.

In six of the studies outcomes were reported that did not correspond to the reported object of the PLC (Lim et al., 2016; Moghaddam et al., 2015; Murata et al., 2012; Slavit et al., 2011; Van Es, 2009; Won, 2017). For example Murata et al. (2012) describe how teachers, who have practiced making connections between different representations as a teaching strategy to illustrate a mathematical concept, also develop their own understanding of these connections. This serves as an example of how teachers can develop and deepen their own understanding of mathematics (Object B) when working to develop new teaching strategies (Object C). Eight of the studies describe several outcomes where one corresponds with the object, but where the other outcomes seem unintended (Brantlinger et al., 2011; Cajkler et al., 2014; Gamoran Sherin & van Es, 2009; Gee & Whaley, 2016; Goodnough & Murphy, 2017; Hunter & Back, 2014; Ni Shuilleabhain & Seery, 2018; Widjaja et al., 2017).

Changed norms for collaboration

When the described outcome was categorised as changed norms for collaboration, the studies reported on the norms established in the group during the time that the PLC was running. The norms that were described to having been established in the PLC were mostly norms regarding what is expected in and from a learning session. In each learning session teachers were expected to behave a certain way, but teachers also had expectations of what was to be discussed and in what way. In several studies there are descriptions of how teachers had moved from focusing on and discussing overarching or general teaching issues, to focusing on and examining mathematical content and discussing specific issues in mathematics education, such as ways of introducing mathematical content (Borko et al., 2008; Brantlinger et al., 2011; Gamoran Sherin & van Es, 2009; Hauge & Norenes, 2009; Slavit et al., 2011; Van Es, 2009). The way issues were discussed was also something that changed, and several studies described how a more critical approach to mathematics teaching, mathematical ideas, and pedagogical ideas had developed (Brantlinger et al., 2011; Gellert, 2013; Lesseig, 2015; Van Es, 2009). In these studies, the teachers were described as having developed new norms on how to act to contribute to the discussion in the learning sessions. Ways of inviting others into a discussion, ways to examine different perspectives, and building on others' ideas to deepen discussions, were all examples of behavior that the teachers developed (Brantlinger et al., 2011; Gellert, 2013; Lesseig, 2015; Van Es, 2009; Warwick et al., 2016). Teachers also showed an increased willingness to openly recognise shortcomings, to share material from their classrooms, and to invite others to reflect critically on their teaching (Borko et al., 2008; Brantlinger et al., 2011).

Enhanced understanding of mathematics and its teaching

When the described outcome was categorised as enhanced understanding of mathematics and its teaching, teachers developed their understanding of mathematics and its teaching as a result of their participation in the PLC. Teachers were also described as having developed their understanding of what is required to increase students' learning in mathematics. For example, teachers were described as having gained an increased understanding of how tasks can be sequenced in and between lessons to highlight mathematical ideas, or the importance of supporting students' reasoning through careful questioning (Brantlinger et al., 2011; Gee & Whaley, 2016; Hunter & Back, 2014; Lesseig, 2015; Lim et al., 2016; Ni Shuilleabhain & Seery, 2018; Wake et al., 2016; Widjaja et al., 2017).

Another aspect of teaching that was described as an outcome of the PLC was increased teachers' understanding of how certain mathematical content can be introduced and taught. Examples included an understanding of how to design teaching that engages students, and how and why a variety of representations and teaching materials can enhance students' learning (Borko et al., 2008; Cajkler et al., 2014; Gee & Whaley, 2016; Hunter & Back, 2014; Lim et al., 2016; Murata et al., 2012; Ni Shuilleabhain & Seery, 2018; Widjaja et al., 2017). These are examples of how teachers developed a deeper understanding of mathematical concepts as well as concepts from mathematics education. When teachers have developed their understanding of mathematical concepts and ideas from mathematics education, they can use this to better examine and understand curriculum material and standards (Borko et al., 2008; Campbell & Stohl Lee, 2017; Gee & Whaley, 2016; Gellert, 2013; Hunter & Back, 2014; Lesseig, 2015; Murata et al., 2012; Slavit et al., 2011). An increased ability to use concepts from mathematics education also offers teachers a more precise language with which to discuss their teaching (Lesseig, 2015).

Enhanced ability to design and carry out mathematics teaching

When the described outcome was categorised as enhanced ability to design and carry out mathematics teaching, teachers developed their ability to design and carry out mathematics teaching through an enhanced ability to identify and analyse different aspects of students' mathematical reasoning, understandings, and needs, and to adapt the teaching accordingly (Gamoran Sherin & van Es, 2009; Gee & Whaley, 2016; Goodnough & Murphy, 2017; Widjaja et al., 2017). Teachers were described as having enhanced their ability to collect and analyse different student and classroom data (Borko et al., 2008; Brantlinger et al., 2011; Gamoran Sherin & van Es, 2009; Gellert, 2013; Hauge & Norenes, 2009; Lesseig, 2015; Murata et al., 2012; Slavit et al., 2011). Teachers were also described as having changed their classroom norms regarding who speaks and who is responsible for articulating ideas, so that they now leave considerably more of the talking space to their students. By doing this they gained more insight into their students' mathematical thinking and could adjust their teaching to align with this (Borko et al., 2008; Cajkler et al., 2014; Gamoran Sherin & van Es, 2009; Gee & Whaley, 2016; Goodnough & Murphy, 2017; Hauge & Norenes, 2009; Hunter & Back, 2014; Moghaddam et al., 2015; Ni Shuilleabhain & Seery, 2018; Ruthven, 2014; Widjaja et al., 2017; Won, 2017). In several of the studies the teachers found that allowing students to use most of the talking space revealed more sophisticated mathematical reasoning, and more knowledge, than they expected (Cajkler et al., 2014; Moghaddam et al., 2015; Widjaja et al., 2017). Horn and Kane (2015) note in their study that in PLC concerning a specific teaching strategy, it appears that teachers who are experienced in using this strategy benefit more than teachers who are unfamiliar with it.

Some of the studies also reported outcomes that were not specific to mathematics. For example, Hunter and Back (2011) and Slavit et al. (2011) reported that the members of the PLC reported an enhanced understanding of group processes and ability to analyse data.

Discussion

When the PLC described in this article were analysed using CHAT, several similarities emerged. Features such as participants, distribution of work, and connections to a larger community were

very similar across contexts. It is possible that this similarity Is explained by the globalised world in which endeavours such as video clubs or lesson studies have been researched, promoted, and adopted by school systems everywhere. This similarity could also possibly be explained by the relative homogeneity of school systems in different countries especially in the western world from which most of this research, published in English, derived. It is possible, however, that some aspects of PLC are subtle and complex and therefore difficult to describe in such a way that differences can be identified. In this case more research is needed to identify and understand such differences.

We claim that the three identified objects of PLC in mathematics theoretically constitute three different activity systems. The three systems correspond in different ways with different objects. Thirteen of the studies (see Appendix C) could be said to describe more than one object, thus constituting parallel activity systems. In cases where more than one object was reported, Object A (developing norms for collaboration) appeared to precede Object B (Developing teachers' understanding of mathematics and its teaching) and/or Object C (Develop teachers' repertoire of teaching strategies) while Object B often preceded Object C. It is possible that objects were part of PLC but were either an implicit part or not spelled out in the research report. It is reasonable to assume that the reported objects in the studies corresponded to the described outcomes, and there are examples of studies where such correspondence was described. These are however, few in number. It was more common for the object to correspond to the outcome only partially, or not correspond at all. There were studies that report on outcomes that correspond with Object A and Object B, even if these objects were not reported as part of the PLC. In these cases, it appears as if changed norms, and enhanced understanding, were outcomes that are developed alongside teachers' enhanced ability to design and carry out mathematics teaching (Cajkler et al., 2014; Gamoran Sherin & van Es, 2009; Goodnough & Murphy, 2017; Hunter & Back, 2014; Ni Shuilleabhain & Seery, 2018; Widjaja et al., 2017). These outcomes were perhaps not entirely intended, but nonetheless were welcome outcomes of PLC in which the object was to develop teachers' teaching repertoires. Would it then be most productive to introduce this object and assume that the others will develop consequently? We believe there is reason for caution here. We claim that the studies differed in the way they highlighted and distinguished the object of developing norms that allowed for collaboration. In some studies, these norms were not mentioned, possibly because issues regarding such norms in the PLC, were not visible in the data. In other studies, the object was mentioned as a transition object, something to which few participants paid attention. In both these cases it was possible that challenges in establishing norms existed but were not highlighted, much less resolved. Highlighting the development of norms for collaboration, as an object of the PLC, is one way to deal with such challenges.

The potential problem of not highlighting the object of developing norms for collaboration did not appear to be equally grave for the other two objects: developing teachers' understanding of mathematics and its teaching (Object B), and developing teachers' repertoire of teaching actions (Object C). Even if the development of teachers' understanding of mathematics and its teaching is described as preceding the development of teachers' repertoire of teaching actions, we do not perceive the same risk with failing to highlight the difference between them. Developing knowledge about the mathematics and its teaching, and developing teachers' repertoire of teaching strategies, can be perceived as two concurrent aspects of improving teaching (see e.g., Gee & Whaley, 2016; Gellert, 2013; Hauge & Norenes, 2009; Wake et al., 2016).

This can be compared to many constructivist views of mathematics (see e.g., Cobb et al., 1992; Hmelo-Silver et al., 2007), in which problem solving is seen as an activity from which students can develop an understanding of facts, concepts, and connections that they use to refine their problem-solving strategies in mathematics, in an on-going cycle. During learning sessions, in which teachers worked collaboratively to inquire into their teaching, they enhanced their understanding of the mathematics, whilst concurrently developing their ability to design teaching that incorporates this understanding.

The outcomes of the activity systems that are specific to mathematics are dependent, not only on the object/s that are stated, but also on the mediating artifacts used. Artifacts such as mathematical problems, research findings from mathematics education research, or curricular documents, generate discussions on issues that are specific to mathematic classrooms (see e.g., Brodie, 2013; Brodie & Shalem, 2011; Gellert, 2013; Gibbons et al., 2017; Goodnough & Murphy, 2017; Lesseig, 2015). If PLC are to generate outcomes that are specific to mathematics teaching, it is reasonable to assume that the teacher leader, who selects, presents, and organises the discussions around the mediating artifacts, affects the outcome as much as the mediating artifacts themselves. In many of the studies the person leading the PLC was a researcher, or someone from outside the school, with expertise in using different artifacts to organise activities that have the potential to develop mathematics teaching (Gamoran Sherin & van Es, 2009; Taylor, 2012; Wylie et al., 2008). It can be assumed that schools do not always have access to, or resources to acquire access to, researchers or other experts to lead their PLC in ways that lead to outcomes that are specific to mathematics teaching. In a situation where school authorities look to PLC to advance teachers' competence and improve mathematics teaching, finding other ways to support and lead teachers in these processes is essential. If schools are to implement productive cultures of collaboration and critical inquiry, in which teachers competently and continuously improve their teaching, it is imperative to consider ways to support teachers that do not rely on external actors.

Further research

Most of the studies in our data investigated PLC as projects led by researchers. Since previous research suggests that developing teaching is a continuous part of the collaborative school practice and part of being a professional teacher (Hargreaves & Fullan, 2012; Jaworski, 2006), we believe that more research is needed on how such practices can be independent of external support. We further suggest that such research is focused on subject specific PLC and explores how these can be initiated and organised locally in ways that afford teachers opportunities to develop all the three objects identified in our study.

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Appendix A: Studies included in the literature review

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Appendix B: Table showing the object of the studies

Developing norms for collaboration	Developing teachers' understandings about mathematics and its teaching	Developing teachers' repertoire of teaching actions
Borko et al. (2008)	Borko et al. (2008)	Borko et al. (2008)
Dobie and Anderson (2015)	Brantlinger et al. (2011)	Cajkler et al. (2014)
Lim et al. (2016)	Brodie (2013)	Gamoran Sherin and van Es (2009)
Moghaddam et al. (2015)	Brodie and Shalem (2011)	Gee and Whaley (2016)
	Campbell and Stohl Lee (2017)	Gellert (2013)
	Gee and Whaley (2016)	Gibbons et al. (2017)
	Gellert (2013)	González et al. (2016)
	Gibbons et al. (2017)	Goodnough and Murphy (2017)
	González et al. (2016)	Hauge and Norenes (2009)
	Hauge and Norenes (2009)	Horn and Kane (2015)
	Lesseig (2015)	Hunter and Back (2014)
	Ruthven (2014)	Lesseig (2015)
	Wake et al. (2016)	Lim et al. (2016)
	Warwick et al. (2016)	Moghaddam et al. (2015)
	Wylie et al. (2008)	Murata et al. (2012)
		Ni Shuilleabhain and Seery (2018)
		Ruthven (2014)
		Slavit et al. (2011)
		Takahashi and McDougal (2016)
		Taylor (2012)
		Van Es (2009)
		Vrikki et al. (2017)
		Wake et al. (2016)
		Warwick et al. (2016)
		Widjaja et al. (2017)
		Won (2017)
		Wylie et al. (2008)

Appendix C: Summary of outcomes sorted by object

	Changed norms for collaboration	Enhanced understanding of mathematics and its teaching	Enhanced ability to design and carry out mathematics teaching	General pedagogical outcomes	No outcome reported
Studies with Object A					
Dobie and Anderson (2015)					x
Studies with Object B					
Brantlinger et al. (2011)	x	x		x	
Brodie (2013)					x
Brodie and Shalem (2011)					x
Campbell and Stohl Lee (2017)		x			
Studies with Object C					
Cajkler et al. (2014)	x	x	x		
Gamoran Sherin and van Es (2009)	x		x	x	
Goodnough and Murphy (2017)	x		x		
Horn and Kane (2015)			x		
Hunter and Back (2014)		x	x		
Murata et al. (2012)		x		x	
Ni Shuilleabhain and Seery (2018)	x	x	x		
Slavit et al. (2011)		x		x	
Takahashi and McDougal (2016)					x
Taylor (2012)					x
Van Es (2009)	x				
Vrikki et al. (2017)					x
Widjaja et al. (2017)	x	x	x		
Won (2017)	x	x			
Studies with Object A and Object B					
-					
Studies with Object A and Object C					

Lim et al. (2016)		x	x		
Moghaddam et al. (2015)			x		
Studies with Object B and Object C					
Gee and Whaley (2016)	x	x	x		
Gellert (2013)	x	x		x	
Gibbons et al. (2017)					x
González et al. (2016)					x
Hauge and Norenes (2009)	x		x	x	
Lesseig (2015)	x	x		x	
Ruthven (2014)	x		x		
Wake et al. (2016)		x			
Warwick et al. (2016)	x				
Wylie et al. (2008)					x
Studies with Object A, Object B and Object C					
Borko et al. (2008)	x	x	x	x	