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Research paper

Key actors leading knowledge brokerage for sustainable school improvement with PLCs: Who brokers what?

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HIGHLIGHTS

- Brokering PLC's advantages and organizational matters seems important for sustainability.
- Experience was important, while formal position was not as critical for being a key actor.
- Key actors supported a high-quality infrastructure for knowledge brokerage.
- Key actors in knowledge brokerage fit different profiles.

ARTICLE INFO

ABSTRACT

This study investigated knowledge brokerage key actors, in schools that realized sustainable school improvement through professional learning communities (PLCs). To gain insight into what knowledge key actors brokered and how they brokered knowledge, key actors at five secondary schools that worked sustainably with PLCs participated in an in-depth mixed-method study. The findings showed what types of knowledge were brokered and through what activities, what characteristics of key actors were important for knowledge brokerage, and how key actors fit different profiles. These insights can help schools improve their knowledge brokerage as they work towards sustainable school improvement.

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Professional learning communities (PLCs) are promising as a way to realize school improvement (Stoll et al., 2006). PLCs are groups of school staff members who meet regularly. Those groups discuss theory, practices, and experiences on a specific theme related to their own school, aiming to apply the knowledge that they have created and learned to improve teaching and student learning (Bruns & Bruggink, 2016; Stoll et al., 2006). These discussions help challenge teachers' thinking, which is a fundamental part of changing their practice (Daly & Stoll, 2018) and thus of school improvement.

It is important to sustain the PLC's way of working, because then schools work continually on school improvement. This is hereafter referred to as sustainable school improvement. In line with previous studies on sustainability, that identify sustainability of professional development approaches as achieved when its core components are part of the organizational routines (e.g., Bambara et al., 2012; Bean et al., 2015; Larsen & Samdal, 2008; Tam, 2009), we consider PLC's way of working sustained when its core components are intentionally and permanently woven throughout the organization.

Knowledge brokerage (KB) is key for sustainable school improvement (e.g., Coburn et al., 2009; Stoll et al., 2006). In brief, KB is the communication and discussion of knowledge that is

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acquired and further developed in the PLC between PLC members and their colleagues outside the PLC in the school (Farley-Ripple et al., 2017; Malin et al., 2018). Discussion of the knowledge that is constructed by the staff members who participated in the PLC is aimed at helping all staff members to improve their teaching. KB can thus ensure that the whole school learning community becomes engaged or as Argyris and Schön (1996) would call it, for organizational learning to take place. They define organizational learning as a process in which members (i) detect aspects that can be improved and work on that by restructuring organizational theory of action and (ii) embedding the results of their inquiry in organizational maps, and members' minds and practices. The work of the PLC by itself focusses on the first part of organizational learning, and KB is necessary to realize the second part.

Sustainable school improvement and KB seem challenging (e.g., Fullan, 2016). Schools can stop working with the PLC or no longer carry out all core components (e.g., Hubers, 2016; Sterman, 2012). Distributed leadership can play an important role in both sustainable school improvement and KB (Azorín et al., 2019; Hubers, 2020; King, 2016; Lee & Louis, 2019). From a distributed leadership perspective, leadership concerns all activities tied to the core work of the school that are designed by the school's staff members to influence the motivation, knowledge, or practices of other members of the school and that can be carried out by different staff members (Harris & DeFlaminis, 2016; Spillane, 2006; Woods & Roberts, 2016). Distributed leadership affects sustainability, because it can contribute to supporting and motivating staff members (e.g., Andreou et al., 2015; Leithwood et al., 2020). Moreover, distributed leadership affects KB because it can contribute to access to and motivation for brokering knowledge (e.g., Brown et al., 2020; King, 2016). Those who lead KB processes, also called key actors, seem therefore important for sustainable school improvement.

To date, research on key actors in both KB processes in general (Ward, 2017) and KB processes in relation to distributed leadership and sustainability (Malin & Brown, 2020) is scarce. This study therefore aims to identify key actors and their KB in schools that realized sustainable school improvement with PLCs, as this can help schools improve their KB (Farley-Ripple & Grajeda, 2020; Ward, 2017). In our research model (see Fig. 1), we focused on the following questions:

1. *Who* are the key actors in KB in schools that have realized sustainable school improvement with PLCs?

2. *What* knowledge do these key actors broker?
3. *How* do these key actors perform KB?

We will briefly review the literature around PLCs for sustainable school improvement and KB to clarify our research model. We will zoom in on the school staff members who engage in KB, on the types of knowledge that can be brokered, and how that knowledge can be brokered.

1. PLCs for sustainable school improvement

PLCs can be an important context for professional development. The premise is that teachers develop professionally in PLCs because they discuss teaching and learning, which fosters the collective construction of knowledge and leads to improved student learning and school improvement (Dobie & Anderson, 2015; Doğan & Adams, 2018; Lomos et al., 2011; Vescio et al., 2008).

Often, PLC members also carry out practice-based research focusing on the improvement of teaching and student learning in order to achieve that goal. Examples of such PLCs are data teams and lesson study teams. In data teams, a group of teachers and school leaders use data to solve a classroom level (e.g., low mathematics achievement) or school level (e.g., grade retention) problem through a cyclic procedure (Schildkamp et al., 2016). The goal is thereby both to improve the quality of education at their school and to encourage professional development in data use to help solve future educational problems (Schildkamp & Poortman, 2015). In lesson study teams, a group of teachers develop and observe live lessons with a focus on student learning (De Vries et al., 2017). The goal of lesson study teams is to systematically improve teaching and student learning in classrooms (Lewis et al., 2006). Both types of PLCs engage in what can be called an inquiry research cycle, based on data.

Research shows that both types of PLC can improve teacher and student learning, making it important to sustain the school improvement they produce. Data teams have been found to improve teachers' data literacy (Kippers et al., 2018), for example, as well as student achievement (Poortman & Schildkamp, 2016). Lesson study teams have been found to improve teachers' knowledge and skills (e.g., Willems & Van den Bossche, 2019) and their meaning-oriented learning (i.e., wanting to know *why* something works; Vermunt et al., 2019), which in turn can affect student learning (Dudley et al., 2019). Schools working with these types of PLCs will be the focus of this study.

KB about knowledge acquired and developed in the PLC		
The key actors (RQ 1)	**The brokered knowledge (RQ2)**	**The way knowledge is brokered (RQ3)**
Characteristics: - School role - Level of experience - Engagement with research	*Knowledge related to:* - Focus - Process and outcomes - Approach	**Two-way KB** *Quality of relationships:* - Reciprocated relationships - Intensity = sharing and/or joint work	**One-way KB** *Quality of relationships:* - Reciprocity not needed - Intensity = storytelling and/or aid and assistance
		Activities: - Knowledge management - Linkage and exchange - Capacity building

Fig. 1. Research model.

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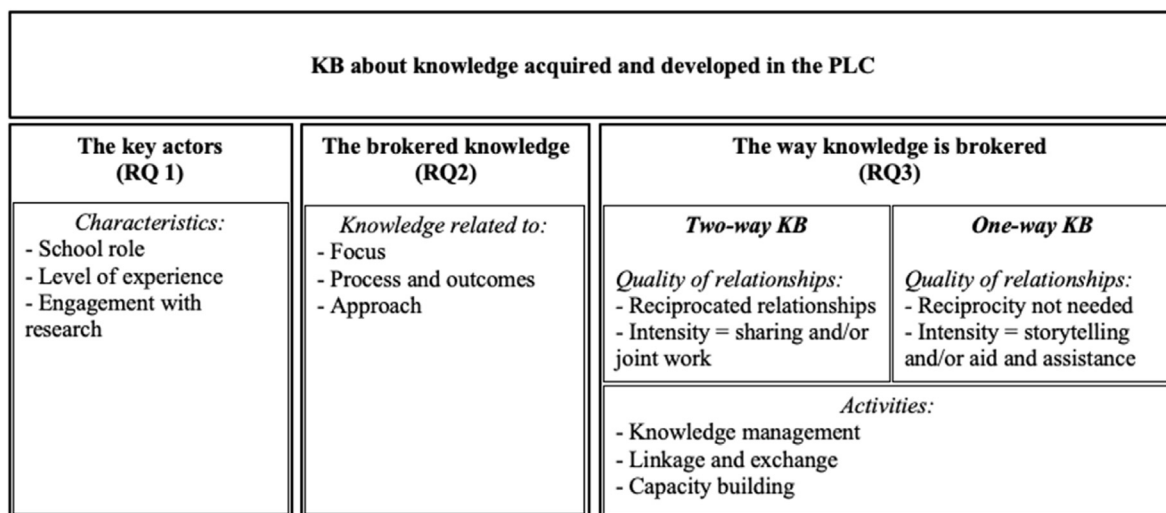
While the work of the PLC is important, the flow of knowledge is critical in order to involve all staff members in the process (Stoll et al., 2006) and thereby move towards sustainability (Hubers, 2020). Several studies show that the flow of knowledge can influence sustainability (e.g., Andreou et al., 2015; Benz et al., 2004; Gaikhorst et al., 2017). To be able to weave the PLC's core components intentionally and permanently throughout the school organization, the work of the PLC needs to spread throughout the school organization − independent of the level of the problem the PLC is focusing on. For example, although the results of a PLC that focusses on teaching fractions might not be directly applicable for a physical education teacher, this teacher can challenge the work of the PLC, pose critical questions, and engage in a dialogue of discussing different opinions and practices. This helps getting others involved and is an opportunity to receive feedback and support for the work of the PLC (Gaikhorst et al., 2017), but also helps the non-PLC members to think critically about and refine their own practices (Brown et al., 2020). Additionally, the flow of knowledge helps others become aware of the benefits of working with the PLC (Benz et al., 2004), possibly making others enthusiastic about working with the PLC too. The flow of knowledge related to the PLC is thus crucial for the PLC to become an integral part of the daily school routines, and thus sustainable.

PLC members can work together and involve colleagues with PLC-related knowledge through social interactions and exchanges (Liou & Daly, 2014). According to social capital theory, knowledge is namely constrained in the relationships between individuals (Lin, 2009). This can be "extracted" through social networks (Liou & Daly, 2014). Social networks in the context of a school consist of relationships among the school staff members − school leaders, team leaders, teachers, and so on (e.g., Borgatti & Halgin, 2011). These relationships represent the social dynamics within the school and can support or constrain the spread of knowledge throughout the school (Daly, 2010). The spread of PLC-related knowledge can be analyzed in a specific social network, namely a 'reform network' (cf. Cole & Weibaum, 2010). This social network specifically contains information on the relationships concerning the spread of PLC-related knowledge.

The position of each person within a social network, or the social structure, determines the opportunities for and circumstances of social relationships (Casciaro, 1998). An important structural position, especially for sustainable school improvement, is known as a knowledge broker.

2. Knowledge brokerage

Knowledge brokers are important for sustainable school improvement, as they are involved in KB. We define KB, in line with Malin et al. (2018) and Farley-Ripple et al. (2017), as a dynamic and complex set of actors, activities, and motivations within which knowledge created within the PLC is exchanged, transformed, and otherwise communicated with colleagues who did not participate in the PLC. KB thus implies the movement of resources through connections between individuals, and knowledge brokers make that happen.

For the KB related to the PLC to take place, the staff members who are knowledge brokers, the knowledge that is brokered and the brokerage process are important. These will be discussed separately below.

2.1. Key actors leading the KB process (RQ1)

Staff members differ in their significance as far as KB, with some being more structurally important than others within a social network (Scott, 2017) and thus more important for the KB process

for sustainable school improvement. These more important staff members in terms of social structure are called key actors and are identified based upon their prominence in the network (Rodway, 2018). Key actors' prominent position in the network makes them leaders. Their position permits them to access and broker knowledge more easily compared to others who are not prominent in the network (Rodway, 2018), so key actors can influence the motivation, knowledge, or practices of other organizational members (Harris & Spillane, 2008; Spillane, 2006), especially related to the PLC and its results.

There are different ways to identify key actors, and social network measures are used to do so (Downey, 2020; Rodway et al., 2021). For sustainability, it is important that the constructed and acquired knowledge reaches others who did not participate in the PLC intervention. Identifying the staff members in schools who together reach the broadest spread of staff members seems crucial, therefore. Measures that help with that are degree centrality and betweenness centrality. *Degree centrality* measures the direct influence of each person in the network. Higher degree centrality means that a person is connected to more people (Daly, 2012). *Betweenness centrality* measures the number of times each person sits between two persons who are otherwise disconnected in the network. Higher betweenness centrality means that a person is connected to more other persons who are otherwise isolated from the social network that is researched (Daly, 2012).

2.1.1. Characteristics of key actors

Previous research has looked at school role, level of experience, and engagement with research (e.g., Farley-Ripple & Grajeda, 2020) as characteristics of key actors. *School role* indicates the role the staff member occupies at the school, such as teacher of a certain subject or principal. A staff member's school role is assumed to have an influence on the number of colleagues they are in contact with. For example, a staff member in a leading position is more likely to reach out to more and different people compared to an individual who teaches one subject. More contacts make reaching others in the school easier.

Level of experience indicates the numbers of years a staff member has been working in education and how many years they have worked at the current school. The less experience a staff member has, the less they are assumed to be part of the school's network (Van Waes et al., 2018). The more experience a staff member has, the more time they have had to craft relationships and become part of the school's network. This makes it easier to reach others in the school.

Engagement with research indicates the research activities the staff member is involved in Farley-Ripple & Grajeda (2020), which in this study is the inquiry research conducted in the data team or lesson study team. We therefore look at *participation in the PLC*. It is easier for a staff member to engage in KB when they participated in the PLC, as they have direct access to and were involved in creating the knowledge (Van den Bossche et al., 2011).

Although these characteristics seem beneficial for KB, not all studies have found relationships between these characteristics and being a key actor in KB (Farley-Ripple & Grajeda, 2020). Further research into these characteristics is therefore necessary.

2.2. The knowledge being brokered (RQ2)

By participating in PLCs, staff members acquire and further develop their knowledge (e.g., Popp & Goldman, 2016; Stoll et al., 2006). Brokering this 'PLC' knowledge ensures that more and more staff members engage with this knowledge and improve their teaching by means of this knowledge, which is essential for sustainability (Hubers, 2020).

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Based on the work of Hubers et al. (2019), we consider that staff members who participate in a PLC acquire and develop three types of knowledge that can be brokered.

1. Knowledge related to the *focus* of the PLC is knowledge about the problem or question the PLC is focusing on. For data teams, this can, for example, be disappointing mathematics results. For lesson study teams, this can, for example, be students' failure to use a specific reading strategy.

2. Knowledge related to the *process and outcomes* of the PLC is knowledge about the results of the different steps taken during the specific PLC process of this PLC. For data teams, this could be their experience with the measures implemented based on data to improve their mathematics results. For lesson study teams, this can, for instance, be their experience with using didactics to improve their students' use of a specific reading strategy.

3. Knowledge related to the *approach* of the PLC is knowledge about the general method used in the PLC process. Contrary to the types of knowledge described before, this type of knowledge is about the approach in general and does not provide specifics on the results or process of a particular team. Knowledge related to the data teams approach is defined as data literacy. Data literacy is the ability to use data, and consists of five components: set a purpose, collect data, analyze data, interpret data, and take instructional action (Beck & Nunnaley, 2020; Gummer & Mandinach, 2015; Kippers et al., 2018). Knowledge about the lesson study approach concerns the ability to carry out lesson study and relates to the steps of the lesson study cycle. This cycle consists of six phases: formulate lesson and student goals and a research question, plan the lesson, give the lesson, observe the lesson and interview students about their learning and the research goal, discuss the lesson and interview results, revise the lesson and teach it again, and reflect on the entire lesson study process (Stepanek et al., 2007).

2.3. How knowledge is being brokered (RQ3)

KB can happen in two ways. First, when PLC members communicate the knowledge that has been developed to their colleagues who did not participate in the PLC, this is called *one-way KB* (Malin et al., 2018). One-way KB helps colleagues to get to know about the PLC, but does not necessarily mean they are going to use the knowledge. Second, when colleagues who did not participate in the PLC also discuss the developed knowledge with PLC members, and describe challenges or emerging trends, this is interactive, and is called *two-way KB* (Malin et al., 2018). These discussions are more likely to challenge teachers' thinking. As challenging teachers' thinking is important for changing practice (Daly & Stoll, 2018), it is our assumption that two-way KB is more effective compared to one-way KB.

2.3.1. Quality of relationships

The quality of relationships in social networks can be considered an important aspect of how KB takes place. Namely, the relation between two persons can help or obstruct the actual brokering of knowledge. Higher quality relationships make it easier to broker knowledge (Daly, 2010). Two central aspects related to relationship quality in this respect are reciprocity and intensity.

Reciprocity is present in mutual relationships through which mutual exchange of resources and the creation of norms between staff members can take place, and can be determined by means of social networks (Daly, 2012). Reciprocated relationships thus seem necessary for two-way KB (Malin et al., 2018), and are associated with the likeliness of organizational change (Mohrman et al., 2003)

and sustaining change efforts (e.g., Daly & Finnigan, 2011).

The intensity of relationships can be considered in terms of the type of interaction involved. According to Little (1990), teachers tell stories, provide aid and assistance, share, or engage in joint work — with the last being the ideal form of interaction. Storytelling and providing aid and assistance can be considered one-way KB (Malin et al., 2018), as those types of interaction only need activity from one person (Little, 1990). Sharing or joint work is necessary for two-way KB (Malin et al., 2018), as here the "ground is laid for productive discussion and debate" (Little, 1990, p. 518). The two latter types of interaction make relationships more intense and are more likely to lead to the desired changes in practice.

To sum up, the combination of reciprocated and high-intensity relationships is crucial for two-way KB.

2.3.2. Activities

The lack of research into concrete activities that make KB happen has been identified as a gap in the literature (Ward, 2017). The activities that previous research did identify (Farley-Ripple & Grajeda, 2020; Ward et al., 2009) can be categorized as:

1. *Knowledge-management* activities, which are related to navigating, managing and disseminating research and other evidence, for example, through facilitating discussion or sending a newsletter. Dissemination can be supported by artifacts, which help communication by creating shared vocabulary and identity (Star, 2010). Examples are documents and tools.

2. *Linkage and exchange* activities, which focus on the development of positive relationships between the PLC participants and their colleagues outside of the PLC, for example, through providing assistance or support, evaluating the needs of staff members, and translating research into understandable language or format.

3. *Capacity-building* activities, which are related to educating colleagues who did not participate in the PLC and developing in them the skills learned in the PLC, for example, through offering formal learning opportunities such as workshops.

These activities can be either one-way or two-way KB.

3. Method

To identify key actors, the knowledge that they broker and the activities they use to do so in KB processes in secondary schools that realized sustainable school improvement with a PLC intervention, we used a mixed methods case study approach, in order to better grasp the complex phenomena of KB in schools compared to using only a qualitative or quantitative approach (Creswell & Clark, 2007; Greene & Caracelli, 1997). Observational, questionnaire and interview data were collected and analyzed.

3.1. Participants

Five secondary schools in the Netherlands were the focus of this study. The school system in the Netherlands is decentralized and there is no national curriculum. Teachers teach towards core curriculum standards, but these objectives are general (OECD, 2008, 2010). School staff members thus have the freedom to decide what and how they want to teach, and to implement curriculum innovations. Background information for each school is presented in Table 1.

Each school in this study started working with either a within-school lesson study team or a data team two to five years ago and were still working with it, three with data teams, and two with lesson study teams. The schools were not in contact with one

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another, nor were part of some kind of consortium. All of the schools were coached by a university employee on working with the PLC during the first year the school worked with it. The researchers were no part of the PLCs.

One school working with data teams kept the composition of the data team the same over the years; the other two schools changed the composition of the data team over time. Both schools working with lesson study teams involved new colleagues in lesson study each year, in addition to colleagues who kept working with lesson study. All schools sustainably worked on school improvement as the schools were still working with the PLC after more than two years, even when the external coaching was finished.

A total of 248 teachers and 20 formal school leaders at these five schools completed a social network questionnaire. Based upon the questionnaire results, three key actors per school were selected. They were invited for interviews.

3.2. Procedure

Participating schools were selected based on purposive sampling (Creswell & Clark, 2007), and recruited from the researchers' network by email and selected based upon their willingness to participate. These schools were part of two larger projects, one focused on introducing data teams and the other focused on introducing lesson study in the schools, and of a larger study (Van den Boom-Muilenburg, 2021). The schools were selected because they a) finished the initial implementation phase and b) considered the PLC to be relevant for school improvement and c) explicitly intended to keep working with the PLC. The study was approved by the ethical committee of the researcher's university.

At each school, activities that might contribute to sustainable school improvement with PLCs were observed over an extended observation period of approximately 168 h, divided over 6−8 successive weeks per school. This observation period focused on an entire cultural group, here all staff members in one school, and was intended to describe the shared patterns of values, behaviors, and beliefs through immersion in their day-to-day lives. This is also called fieldwork (Wolcott, 2012) or shadowing (Tulowitzki, 2019). Lessons, meetings and staff room discussions were observed. Field notes were taken on paper and digitally, and were organized by entering them in a logbook at the end of each day.

At the end of the observation period at each school, a social network questionnaire was administered digitally once to all teachers and school leaders at the school.

Key actors were selected per school out of all staff members that were currently working at the school, based upon their degree and betweenness centrality as measured by the social network questionnaire. They were invited for an interview by e-mail. The digital

video-interviews were conducted by the first author, had an average duration of 1 h, were audio-recorded and transcribed verbatim. The transcripts were sent back to leaders for a member check. Adjustments were not necessary.

3.3. Instruments

3.3.1. Logbook

The logbook that was kept during the observation period was developed for a study into the role of leadership in sustaining a PLC's core components (see Van den Boom-Muilenburg, 2021), and addressed questions related to different activities that might influence sustainability. Notes about KB, specifically about the knowledge that was brokered and the activities that were used to broker knowledge, were made as well.

3.3.2. Social network questionnaire

Participants were asked to select the names of colleagues from a list of all teachers and school leaders in response to the question 'Whom do you talk to about [the PLC]?'. This helped to capture the reform network (Cole & Weibaum, 2010). The second question, 'What was the nature of the contact about the PLC with these colleagues?', was used to capture the intensity of the relationship. The colleague names that were selected in the first question appeared on the x-axis. On the y-axis, four categories of relationship intensity were presented: exchanging experiences, aid and assistance, sharing, joint work (cf. Little, 1990). Both questions are presented in Fig. 2. Finally, generic information about the participants was asked for, such as whether they participated in the PLC, their role and teaching experience.

3.3.3. Interview protocol

A semi-structured interview scheme was used to ask the identified key actors about what knowledge they brokered and how they brokered knowledge. Example questions are: 'What was the most recent conversation you had regarding [the PLC] with others who did not participate in [the PLC] about?' and 'Did you ever develop material about [the PLC] and share this with your colleagues?'.

3.4. Analyses

3.4.1. Key actors in the KB process (RQ1)

The response rate per school ranged from 68.4% to 91.3%. No apparent differences in grade levels, educational levels being taught and subjects being taught were evident between the responders and the non-responders. The questionnaire data were analyzed using UCINET software (Borgatti et al., 2002). To

Table 1
Background information per school.

School	Level	Staff members	Students	PLC	Start PLC	Staff members worked with PLC	Composition PLC
A	Senior general Pre-university	76	1000	Data team	5 years prior to study (2013−2014)	5	Differed over years One PLC at the time
B	Pre-vocational	23	200	Lesson study	2 years prior to study (2017−2018)	4	Differed over years Multiple PLCs at the same time
C	Senior general Pre-university	79	1100	Data team	5 years prior to study (2013−2014)	5	Stayed the same One PLC at the time
D	Pre-vocational Senior general Pre-university	110	1400	Data team	3 years prior to study (2015−2016)	20	Differed over years Multiple PLCs at the same time
E	Senior general Pre-university	58	800	Lesson study	5 years prior to study (2015−2016)	29	Differed over years Multiple PLCs at the same time

Fig. 2. Presentation of the social network questionnaire.

determine each staff member's prominence in the network, we calculated degree centrality and betweenness centrality per staff member per school. The five staff members who had the highest score on degree centrality and the five staff members who had the highest score on betweenness centrality were selected. Although we planned to average those scores and select the three staff members who had on average the highest degree + betweenness centrality score, it appeared that the three staff members who scored highest on degree centrality also scored highest on betweenness centrality. The three staff members with the highest degree centrality and betweenness centrality per school had the most prominent positions in the network and were identified as key actors.[1] We normalized the scores to allow for comparison across schools.

Regarding the characteristics of the key actors, the demographic information from the questionnaire was used to describe their school role (i.e., (in)formal leader, teacher, what subject), their level of experience (i.e., how many years of experience in education and at the school), and their participation in the PLC (i.e., yes or no).

3.4.2. The knowledge key actors brokered (RQ2)

We used Atlas.ti to analyze and code the logbooks and interviews for the knowledge related to the school improvement and PLC intervention that the key actors brokered. The types of knowledge served as sensitizing concepts (i.e., knowledge related to focus of the PLC, to process and outcomes of the PLC, and to the PLC's approach, Hubers et al., 2019), by means of which a general sense of reference and guidance in approaching our data was provided (e.g., Bowen, 2006).

The three types of knowledge that served as our sensitizing concepts were used as our main code categories. Additionally, several segments could not be coded with those concepts as they did not cover the segments' content. A selection of these codes was discussed amongst the first author and a researcher outside of the project. They identified two extra types of knowledge in a bottom-

up manner, being 'the advantages of working with the PLC' and 'the PLC's organizational matters'. After this initial round of coding and redefining the coding scheme, the first and second authors independently coded 21 segments (16% of the data) to check the reliability of the coding. The interrater reliability was found to be substantial (Cohen's κ = 0.817; Landis & Koch, 1977). In cases of disagreement, the raters reached consensus on the coding through discussion, after finishing the coding. The first author finalized the coding of the transcripts (for the final coding scheme, see Table 2).

3.4.3. How key actors broker knowledge (RQ3)

3.4.3.1. Quality of relationships. For each key actor and staff member, we looked at the conversations they reported to have with colleagues with whom they did not share membership in the PLC (reciprocated relationships - this is a prerequisite for KB; e.g., Malin et al., 2018). The social network questionnaire data were analyzed with UCINET to calculate reciprocated relationships and level of KB [1 = storytelling (lowest); 2 = aid and assistance; 3 = sharing; 4 = joint work (highest), cf. Little, 1990]. Descriptive statistics were calculated.

Additionally, through three independent-samples *t*-tests in SPSS, we analyzed whether key actors had more reciprocated relationships compared to other staff members, whether they brokered knowledge on a higher level compared to other staff members and whether they used more two-way KB compared to other staff members. Due to the difference in group size (16 key actors vs 330 other staff members), we used an effect size measure that corrects for this, namely Hedges' *g* (Enzmann, 2015).

3.4.3.2. Activities. Regarding the activities key actors used to broker knowledge, the logbooks and transcript of the interviews were analyzed. The activities were coded using Atlas.ti. The categories of KB activities (i.e., knowledge management, linkage and exchange, capacity building, cf. Farley-Ripple & Grajeda, 2020; Ward et al., 2009) served as sensitizing concepts (e.g., Bowen, 2006).

The categories of KB activities were used as our main code categories. The codes within each code category were derived bottom-up. The segments were provided with a very detailed code at first (e.g., 'ask colleagues for advice on hypotheses' or 'ask others to provide input on specific question of PLC on whiteboard'). After

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[1] Chris no longer worked at School C and could not be interviewed. For that reason, four staff members were selected as key actors at School C. In that way, three staff members at all schools could be interviewed.

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Table 2
Coding scheme for knowledge key actors brokered.

Knowledge related to …	Fragments concerning …
..the focus of the PLC	Knowledge about what problem or question the PLC is focusing on
..the process and outcomes of the PLC	Knowledge about the results of the different steps taken during the PLC process
..the approach of the PLC	Knowledge about data team steps/data literacy (set a purpose, collect data, analyze data, interpret data, and take instructional action) or lesson study cycle (formulate lesson and student goals and a research question, plan the lesson, give the lesson and interview students about their learning and the research goal, discuss the lesson and interview results, revise the lesson and teach it again, and reflect on the entire lesson study process)
..the advantages of working with the PLC	Knowledge about how the PLC adds value to the school organization
..the PLC's organizational matters	Knowledge about how the PLC process should or can be carried out within the school organization (e.g., related to planning or facilitating the PLC's work)

all segments were coded, similar codes were grouped and/or merged (e.g., previous mentioned codes were, along with others, merged into 'involve school staff members'). After an initial round of coding and redefining the coding scheme, the first and second authors coded 21 segments (13% of the data) to check the reliability of the coding. The interrater reliability was found to be substantial (Cohen's κ = 0.784; Landis & Koch, 1977). In cases of disagreement, the raters reached consensus on the coding through discussion, after finishing the coding. The first author finalized the coding of the transcripts (for the final coding scheme, see Table 3).

4. Results

4.1. Key actors in the KB process (RQ1)

In Table 4, an overview of the key actors' normalized centrality values and characteristics is presented. The normalized scores allowed us to compare scores across contexts, as it takes into account the different sizes of the networks across the schools. The average degree centrality of the key actors was 0.296 (*SD* = 0.164).

This indicates that each key actor was on average connected to 29.6% of all staff members in their school. The average betweenness centrality of the key actors was 7.084 (*SD* = 5.259). Key actors thus connected on average to seven otherwise disconnected staff members. Regarding key actors' *school role*, at least one key actor at each school had a formal leadership role and at least one key actor did not. The informal leaders (*n* = 10) were teachers of different subjects, mostly mathematics (*n* = 4) and Dutch language arts (*n* = 4). Key actors had on average 19.5 years of *experience* in education (range = 5 to 39) and 11.8 years at their school (range = 4 to 28). Regarding key actors' *participation in the PLC*, all but two key actors in the reform networks of all five schools participated in the PLC. The key actors who did not participate in the PLC were (assistant-)principal.

4.2. The knowledge key actors broker (RQ2)

Table 5 shows that key actors brokered all three types of knowledge identified in the theoretical framework, and two additional types. First, 12 key actors brokered knowledge related to the

Table 3
Coding scheme for activities key actors used to broker knowledge.

Knowledge management	
Oral dissemination	Disseminating knowledge in oral form, for example, through a presentation or conversation
Written dissemination AND	Disseminating knowledge in written form, for example, through an email or newsletters
With artifact	Disseminating knowledge supported with a boundary object
Without artifact	Disseminating knowledge without a boundary object

Linkage and exchange	
Involve school staff members	Building connections with the school staff members, for example, by asking them for input and involving them in the PLC
Provide assistance and support	Helping school staff members with content of the PLC, such as discussing difficult steps, answering questions or connecting them to others who can help them with questions or problems
Make PLC part of school policy	Making PLC part of school policy, for example, through formally adding the PLC to (department) meetings as [agenda point] or planning moments to discuss the PLC
Link school organization and PLC	Discussing the link between the school organization and the PLC, for example, through discussing how the PLC can benefit a department, recognizing problem areas and discussing how the PLC can help in that respect or mentioning the importance of the PLC (when resistance is expressed)
Organize the PLC in the school	Discussing how the PLC is organized in the school, for example, the composition of the PLC and inviting new participants

Capacity building	
Capacity building	Educating colleagues who did not participate in the PLC, and developing in them the skills learned in the PLC, for example, through inviting experts or organizing a "small version" of the PLC

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Table 4
Key Actors, their Characteristics and a summary of the statistics related to their KB.

School	Key actor	Partici-pated in PLC?	School role	Level of experience (years)	Degree centrality[a]	Betweenness centrality[b]	Incoming ties	Outgoing ties	Recipro-cated ties	Intense incoming ties[c]	Intense outgoing ties[c]	Two-way KB ties[d]
A	Amber	Yes	Assistant principal	Education: 17 This school: 16	.400	13.008	.197	.352	.183	.113	.239	.085
	Andrew	Yes	Teacher	Education: 13 This school: 11	.173	2.549	.135	.027	.000	.027	.000	.000
	Arthur	Yes	Teacher	Education: 35 This school: 25	.120	2.078	.069	.028	.014	.014	.014	.000
B	Belinda	Yes	Teacher	Education: 5 This school: 4	.273	7.720	.263	.158	.105	.105	.158	.105
	Bryan	No	Principal	Education: 27 This school: 5	.364	15.332	.158	.211	.105	.053	.211	.053
	Bob	Yes	Teacher & deputy principal	Education: 18 This school: 4	.364	7.937	.158	.368	.105	.105	.211	.105
C	Carol	Yes	Teacher	Education: 10 This school: 9	.410	11.048	.230	.284	.122	.041	.108	.014
	Chris	Yes	Assistant principal	Education: 20 This school: 6	.167	1.678	.122	.054	.054	.041	.000	.000
	Cecilia	Yes	Teacher	Education: 18 This school: 12	.141	1.004	.081	.014	.000	.000	.000	.000
	Charlotte	Yes	Teacher	Education: 8 This school: 7	.218	5.435	.068	.149	.041	.027	.054	.014
D	Danielle	Yes	Assistant principal	Education: 39 This school: 8	.174	4.002	.125	.115	.073	.063	.083	.042
	Debbie	Yes	Assistant principal	Education: 32 This school: 18	.138	2.452	.082	.061	.041	.041	.041	.010
	Doreen	Yes	Teacher	Education: 9 This school: 8	.165	2.165	.039	.108	.020	.000	.098	.000
E	Emily	Yes	Teacher	Education: 12 This school: 12	.421	7.942	.233	.067	.033	.067	.000	.000
	Esther	Yes	Teacher	Education: 19 This school: 15	.526	11.796	.100	.233	.033	.067	.033	.033
	Evelyn	No	Assistant principal	Education: 31 This school: 28	.684	17.194	.067	.182	.018	.006	.018	.000

[a] Degree centrality reflects the number of people who indicated the key actor as an interlocutor for the PLC.
[b] Betweenness centrality reflects the degree to which the key actor occupies a position between two other staff members that are otherwise not connected to the network. Scores were normalized to allow for comparisons across networks.
[c] Intense ties are interactions that in the social network questionnaire were identified as 'sharing' or 'engaging in joint work'.
[d] Two-way KB ties are ties that are both reciprocated and intense.

Table 5
A schematic overview of the knowledge key actors brokered.

School	Key actor	Knowledge related to the PLC's …				
		Focus	Process and outcomes	Approach	Advantages	Organizational matters
A	Amber	X	X	X	X	X
	Andrew	–	X	–	–	–
	Arthur	X	X	–	–	–
B	Belinda	–	X	–	–	–
	Bryan	–	X	–	X	X
	Bob	X	X	X	X	–
C	Carol	X	X	X	X	–
	Chris	X	X	X	–	–
	Cecilia	X	X	X	–	X
	Charlotte	X	X	X	–	–
D	Danielle	X	X	X	X	X
	Debbie	X	X	X	X	X
	Doreen	X	X	X	–	–
E	Emily	X	X	X	X	–
	Esther	X	X	X	X	–
	Evelyn	X	–	X	–	X

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focus of the PLC. For example, key actors told their colleagues the problem the PLC was focusing on and why, as when Debbie stated that it was very important to explain the problem and why the PLC was focusing on that problem. KB about focus provided context for others to understand the reason for and results of the PLC, even when they were not directly experiencing the problem. Amber shared the focus of the PLC in smaller teams, aiming to brainstorm with colleagues who were not part of the PLC about possible causes. The focus of the PLC was often shared in combination with the processes and outcomes of the PLC.

Second, 14 key actors brokered knowledge related to the *process and outcomes* of the PLC. For example, key actors brokered results to others, such as approved or rejected hypotheses or improvement measures that had been developed, or explained how they came to those results. Danielle mentioned how results were discussed during a meeting of school leader, followed by discussion of how the results could be implemented in the organization. Five key actors mentioned that they used anecdotes related to successes, enthusiasm, or lessons learned to broker this type of knowledge. For example, Esther mentioned that some colleagues were afraid that when they observed lessons as part of the PLC cycle, students behaved differently compared to normal classroom situations. She then explained: "(…) We give an example and explain what happened previously. Once, during a lesson observation, all students were talking out loud and (…) did not even notice us". According to Amber, these anecdotes helped colleagues understand the PLC's context: "You can refer to previous experiences, (…) that helps and gives recognition".

Third, 12 key actors brokered knowledge related to the *approach* used in the PLC. For example, key actors explained the PLC cycle to their colleagues and what working with this specific PLC meant for the school. Cecilia said to mention "how [the PLC] works". Doreen explained that at School D, the PLC's approach is so common, because "a large group already worked with [the PLC]", that elaborating on the approach was not always necessary.

In addition to these three categories, we found that eight key actors brokered knowledge related to the *advantages of working with the PLC* For example, Amber explained to a colleague that the PLC "can help with providing answers to questions you face in your daily practice" and Danielle explained that "the data team helped [her] become aware of the fact that [she] acted on her gut feeling often, while this was not always correct, and now look[s] more at data." Esther explained that through lesson study "the department was better able to collaborate" and she "gained more insight into what the students are doing in the lessons" which she used to prepare and adjust her lessons. Key actors also explained the advantages of working with the PLC to resolve conflict when a colleague expressed resistance or to convince someone to participate.

We also found that six key actors brokered knowledge related to the *PLC's organizational matters*. This happened mainly when a colleague asked questions about it. For example, key actors mentioned how many hours were compensated to participate in the PLC, when meetings should take place, or if changes should be made in the organizational structure. The last happened when one PLC was not running well (i.e., less motivation to work with the intervention), and the principal asked Danielle whether the department leader was the cause of this and if they should be replaced, and when Carol discussed with the principal the possibility of getting more compensation for PLC members.

4.3. How key actors broker knowledge (RQ 3)

4.3.1. Quality of relationships

The results concerning the nature of the relationships of each

key actor can be found in Table 4.

4.3.1.1. Reciprocity. For two-way KB to take place, reciprocated relationships are necessary. We conducted an independent samples t-test to compare the proportion of reciprocated ties (i.e., the indicated number of reciprocated ties in the questionnaire divided by the number of all possible reciprocated ties) for key actors to that for their colleagues. The difference was statistically significant and large, $t(15.056) = 4.286$, $p = .001$, Hedges' $g = 3.768$. Hedges' g is an effect size measuring the magnitude of the difference; here, 3.768 standard deviations. This means that key actors had more reciprocated ties with school staff members with whom they did not share membership in the PLC ($M = 0.059$, $SD = 0.052$) than did their colleagues ($M = 0.004$, $SD = 0.010$).

4.3.1.2. Intensity. The room for discussion that is necessary for two-way KB could take place through sharing and joint work. We conducted an independent samples t-test to compare the proportion of incoming sharing and joint work ties (i.e., the indicated number of incoming sharing and joint work ties in the questionnaire divided by the number of all possible sharing and joint work ties) for key actors to that for their colleagues. The difference was statistically significant and large, $t(15.192) = 4.764$, $p < .001$, Hedges' $g = 2.900$. This means that school staff members chose to share and perform joint work related to the PLC intervention more often with the key actors ($M = 0.049$, $SD = 0.036$) than with their other colleagues ($M = 0.006$, $SD = 0.013$).

We also conducted an independent samples t-test to compare the proportion of outgoing sharing and joint work ties (i.e., the indicated number of outgoing sharing and joint work ties in the questionnaire divided by the number of all possible sharing and joint work ties) for key actors to that for their colleagues. The difference was statistically significant and large, $t(15.044) = 3.584$, $p = .003$, Hedges' $g = 3.327$. This means that key actors more often shared and performed joint work related to the PLC intervention with school staff members who were not in a PLC with them ($M = 0.079$, $SD = 0.084$) than did their colleagues ($M = 0.004$, $SD = 0.015$).

4.3.1.3. Two-way knowledge brokerage. For two-way KB to take place, ties need to be both reciprocated and intense (i.e., sharing or joint work). We conducted an independent samples t-test to compare the proportion of those two-way KB ties (i.e., the indicated number of two-way KB ties in the questionnaire divided by the number of all possible two-way KB ties) for key actors to that for their colleagues. The difference was statistically significant and large, $t(15.042) = 2,870$, $p = .012$, Hedges' $g = 2.681$. This means that key actors ($M = 0.029$, $SD = 0.038$) did engage more in two-way KB compared to their colleagues ($M = 0.001$, $SD = 0.007$). Nine key actors did and seven key actors did not engage in two-way KB.

4.3.2. Activities

In Table 6, an overview of the activities key actors used to broker knowledge is presented.

4.3.2.1. Activities related to knowledge management. All key actors used activities related to this category. All activities had to do with dissemination of knowledge related to the PLC. More detailed insight into the activities key actors used to broker knowledge related to knowledge management is presented in Appendix A.

The form in which dissemination happened differed. All key actors used oral dissemination. Oral dissemination took place in the teacher staff room, in hallways between lessons, during formal meetings, or during a presentation. Seven key actors used written

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Table 6
A schematic overview of the activities key actors used to broker knowledge.

School	Key actor	Activities related to …		
		Knowledge management	Linkage and exchange	Capacity building
A	Amber	1, 2	5, 6, 7, 8, 9	10
	Andrew	1	—	—
	Arthur	1	—	—
B	Belinda	1	6	—
	Bryan	1	8, 9	10
	Bob	1	5, 6, 7	10
C	Carol	1, 2, 3, 4	5, 6, 8	—
	Chris	1, 4	6, 7	10
	Cecilia	1, 4	5, 6, 8	—
	Charlotte	1, 2, 3, 4	5, 6, 8	—
D	Danielle	1, 3	5, 6, 7, 8, 9	10
	Debbie	1, 3	6, 7, 9	10
	Doreen	1, 3	5, 8	—
E	Emily	1, 3, 4	5, 6	11
	Esther	1, 3, 4	5, 6, 7, 8	11
	Evelyn	1, 3, 4	7, 8, 9	10

Note. Each number represents an activity. 1 = Oral dissemination, without artifact; 2 = Oral dissemination, with artifact; 3 = Written dissemination, without artifact; 4 = Written dissemination, with artifact; 5 = Involve school staff members; 6 = Provide assistance and support; 7 = Make PLC part of school policy; 8 = Link school organization and PLC; 9 = Organize the PLC in the school; 10 = Invite experts to educate all staff members on (content related to) the PLC; 11 = Arrange for all staff members to experience a "small version" of the PLC.

dissemination. Written dissemination happened through emails and newsletters, and by disseminating minutes of PLC meetings.

Three key actors used oral dissemination accompanied by artifacts; five key actors used written dissemination accompanied by an artifact. Artifacts that were used included an instruction booklet based on which all school staff members could implement the improvement measures that resulted from the PLC. The process and outcomes of the PLC were presented in brief, as well as guidelines for implementing the improvement measures. The key actors at School C developed a flyer in which they presented the results of their PLC. They placed them on the tables in the teacher staff room. These flyers often led to conversations about the PLC. Staff members asked PLC members about details or asked in-depth questions. At School E, posters about the PLC approach and a research article were placed on the walls throughout the school.

Although the dissemination activities sometimes led to two-way KB, these activities themselves were one-way KB.

4.3.2.2. Activities related to linkage and exchange. Fourteen key actors used activities related to this category. Five types of activities were identified. More detailed insight into the activities key actors used to broker knowledge related to linkage and exchange is presented in Appendix B.

First, nine key actors brokered knowledge by *involving school staff members.* For example, School C's key actors together placed a whiteboard in the teacher staff room with a question related to the PLC that all staff members could reply to. These suggestions were discussed later in a meeting. This happened at School B and E as well, but with sticky notes, and at School D through individual conversations with teachers from different departments. Additionally, Amber added a brainstorm-moment to some of the team meetings she initiated. She then asked the staff members to think along concerning a question the PLC was facing. Although she mentioned that it might not have generated ideas immediately, "it makes people think and sometimes staff members came with ideas a day or a week later." Another example was that the key actors of School C invited the staff members who were directly experiencing the problem the PLC members were investigating to attend some of

the PLC meetings so that they could think along with the team. These activities all comprised two-way KB.

Second, 11 key actors brokered knowledge by *providing assistance and support.* Key actors answered questions school staff members had about the PLC. These questions were about the outcomes or the execution of the PLC, for example. Other key actors took it a step further and helped colleagues with the execution of the PLC process. For example, Doreen developed an Excel document that helped a colleague organize test results and run analyses. Others helped by connecting staff members to colleagues or other PLC members who could help them out, for example when a key actor had no time or knew that someone else was more knowledgeable on that subject. Discussing the PLC approach in depth, and more specifically steps that were up for discussion or considered difficult, was another example of helping with the PLC content. For example, Belinda discussed one step of the PLC approach in depth with other staff members; more specifically, she talked about how to carry it out (or not). These activities all comprised two-way KB.

Third, six key actors brokered knowledge by *making the PLC part of school policy.* For example, this was done by the key actors at School C through making the PLC part of the department plans for the departments that worked in a PLC. These departments were asked to elaborate on the implementation of what they learned in the PLC within their departments each school year and add this to their plans. These plans were discussed multiple times per year in meetings with each other and with the school leaders. In those meetings the staff members of the department evaluated their plans and thus how the implementation of that what was learned was going. At Schools A, C, D, and E, key actors made the PLC a repeating item on the agenda of formal meetings, such as yearly meetings between department and school management. Finally, the key actors at all schools added moments to the yearly calendar to present the outcomes of the PLC where all staff members got the opportunity to ask questions. This helped, according to Evelyn, because "you plan something (…) and the last years we also had something to eat and drink while we were discussing (…), and because of this [specially organized] afternoon, no one had an excuse not to be there." These activities all comprised two-way KB.

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Fourth, nine key actors brokered knowledge by *linking the school organization and PLC*. For example, key actors explained what the advantages of the PLC were for a specific department or team and discussed whether the PLC could also have those benefits for the department of the staff members to whom the key actor was talking. Amber triggered her team members with questions such as "(…) can you imagine that within your subject area these [aspects that were researched with the PLC] also play a role, and do you want to research this in a group too?". Key actors also discussed the implications of the results of the PLC for the school or other departments with staff members. They discussed the importance and advantages (described above) of working with the PLC with staff members as well. This often happened when resistance was expressed. Bryan explained to one of his colleagues who had issues because of time that "I put it in the yearly calendar, and although it might cost you your lessons, it does not cost you extra time and you learn from it." Danielle added that she sometimes agreed with criticism from colleagues, such as that a PLC cannot perform generalizable research. She said: "(…) that they are right. But it is more about the teacher's awareness, not react based upon their gut feeling, and to look at the data that is available. And I try to explain that to them." Additionally, key actors recognized problem areas a staff member was explaining that could possibly be worked on with a PLC. In such conversations, they mentioned what the PLC was and how it could help solve the problem a staff member was facing. These activities all comprised two-way KB.

Fifth, five key actors brokered knowledge by *organizing the PLC in the school*. Key actors invited school staff members to participate

and engaged in discussions about the PLC. Moreover, key actors purposefully composed the PLCs. For example, Debbie explained how she aimed to let every department work in a PLC. She purposefully asked staff members from specific departments whether they wanted to participate. Over three years, staff members of each department then worked with the PLC.

4.3.2.3. Activities related to capacity building. Seven key actors used activities related to this category. Activities in this category were observed least often. Two types of activities were identified. Key actors at School E let all school staff members experience a "miniature" version of the PLC. They organized an afternoon with a walkthrough of the full cycle of the PLC. Emily explained that this was done because only a few staff members were working with the PLC, and they wanted to let everyone experience what they were doing and why they were doing it. Key actors at all schools invited experts to talk about (content related to) the PLC, for example, to give a workshop or act as coach of the PLC. These activities were two-way KB.

4.4. Overview

An overview of the results incorporated in our research model is presented in Fig. 3. In sum, we found that all but one characteristic seemed to influence whether a staff member became a key actor. We identified, on top of the three knowledge types that were established in previous research, two additional types of knowledge that key actors brokered. The quality of key actors'

KB about knowledge acquired and developed in the PLC		
The key actors (RQ 1)	**The brokered knowledge (RQ2)**	**The way knowledge is brokered (RQ3)**
Characteristics: - School role: **both formal and informal leaders** - Level of experience: **mid- to late-career** - Engagement with research: **all but two participated in PLC**	*Knowledge related to:* - **Focus** - **Process and outcomes** - **Approach** - **Added value** - **Organizational matters**	*Quality of relationships:* Compared to non-key actors, key actors: - had **more intense relationships** - had **more reciprocated relationships** - used **more two-way KB**

		Activities:
		- Knowledge management:
		    - **Oral dissemination**
		    - **Written dissemination**
		- Linkage and exchange:
		    - **Involving school's staff members**
		    - **Providing assistance and support**
		    - **Making the PLC part of school policy**
		    - **Linking the school organization and the PLC**
		    - **Organizing the PLC in the school**
		- Capacity building:
		    - **Arranging for all school staff members to experience a miniature version of the PLC**
		    - **Inviting experts to talk about (content related to) the PLC**

Fig. 3. Summary of the Outcomes (in Bold) based on our Research Model.

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relationships appeared to be higher compared to their colleagues. And, last but not least, we identified in detail what activities were used to broker knowledge, complementing the categories that were established in previous research. When comparing all these aspects that are important for KB, similarities and differences between key actors became apparent. This will be discussed further in the next section.

5. Conclusion and discussion

In this study we investigated the role of those leading the knowledge brokerage (KB) processes in five secondary schools that sustainably worked on school improvement with PLCs. KB is key for sustainable school improvement (e.g., Coburn et al., 2009; Stoll et al., 2006), as the flow of knowledge related to the PLC seems to be important for the PLC to become an integral part of the daily school routines, and thus become sustainable. A social network questionnaire, observations, and interviews helped us obtain insight into their characteristics (RQ1), the knowledge they brokered (RQ2), the quality of their relationships and the activities they used for KB (RQ3). Our overall results suggest four broad themes: experience is an important factor, while formal position is not as critical for being a key actor in KB; the importance of brokering the PLC's advantages and organizational matters; key actors supported a high-quality infrastructure for KB; and key actors fit different profiles.

5.1. Experience is an important factor, while formal position is not as critical for being a key actor in KB

Our findings suggest that tenure in position is an important area to consider. Results indicate that the vast majority of the key actors, in addition to participating in the PLC, were mid-to late career. Key actors' level of experience thus seemed to be critical for being a key actor in KB in the schools in our study. As proficient understanding of the educational system (e.g., budgets, resources, myriad other issues) seems to be necessary for brokerage (Cooper et al., 2020), novices might lack the credibility and expertise to become efficient brokers. Van Waes et al. (2018) and Liou and Daly (2014) also showed that more experienced staff members were more often sought out by colleagues for advice. Based on our study it seems that these staff members are more likely to take up an important role in KB processes related to sustainability as well.

Perhaps surprisingly, key actors' school role was not critical for KB in the schools we studied. Each of the schools in this study had key actors who played formal and informal leadership roles. On the one hand, it might be easier for formal leaders to reach out to others because of the higher number of colleagues they are in contact with. On the other hand, informal leaders might be necessary to arrive at the trust-level required to realize school improvement (Fairman & Mackenzie, 2015). Informal leaders namely are found to offer encouragement and support (Roby, 2011). Both types of leaders seem important for KB (e.g., Sinnema et al., 2020) and realizing sustainability (Harris et al., 2013; Lee & Louis, 2019).

5.2. The importance of brokering the PLC's advantages and organizational matters

KB about the PLC's focus, process and outcomes, and approach is well established and each type of KB was present in our research.

These results are in line with Hubers et al. (2019). However, our data yielded two additional types of knowledge that key actors brokered that are rarely discussed in the literature. First, we found that key actors brokered knowledge related to the advantages of working with the PLC in their schools. This shows the importance of the PLC and its results for the school. Brokering the advantages helped to convince others of its importance. Additionally, it helped build staff members' trust: by showing how the PLC had improved aspects at the school, staff members saw that it was more than just another intervention that was being implemented. It was an effective one that would be beneficial for the school, which may help to convince them to act in accordance with the PLC. This is especially critical if colleagues are hesitant or even resistant towards (the work of) the PLC. Previous studies have shown that trust and being explicit about the PLC's importance contribute to sustainability (Bambara et al., 2012; King, 2016; Meyer et al., 2017). This study adds that the perception of value added seems to be important for sustained work, too.

We also found that key actors brokered knowledge related to the PLC's organizational matters in their schools. Creating the right organizational conditions is crucial for sustainability (Wolthuis et al., 2021), and talking about organizational matters helps create these conditions. For example, this can be done by prioritizing the work of the PLC through facilitating the use of resources (Brown & Flood, 2019), a topic that was brokered as well. Discussing possible obstacles, such as time, is the first step in finding solutions to overcome them. Talking about organizational matters thus helped contribute to keeping the core components of the PLC as part of the organization.

5.3. Key actors supported a high-quality infrastructure for KB

Key actors not only reached more (diverse) staff members compared to their colleagues, but the quality of their relationships was also higher (i.e., more reciprocated, more intense, and more two-way KB). The infrastructure that these key actors created in their networks was high quality, based upon which they could perform KB easily and in greater depth (Daly, 2010). This indirectly suggests that key actors might be highly trusted by their colleagues, as trust is critical for establishing this type of infrastructure (Liou et al., 2014).

Although two-way KB was rarely reported in the questionnaire, observing and interviewing key actors about KB showed that they carried out ample activities involving two-way KB. This once again shows the importance of combining quantitative and qualitative approaches, especially in connection with considering the actual content and meaning of interactions (Froehlich et al., 2020), which is important for KB.

Key actors made use of this high-quality infrastructure through various activities. All activities could be categorized as either knowledge management (one-way KB), linkage and exchange (two-way KB), or capacity building (two-way KB). This is in line with Farley-Ripple & Grajeda (2020) and Ward et al. (2009). The last category was used least often by the key actors. Because the schools in this study were already some years along in the process of sustainability, brokers might think they no longer need to focus on this.

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5.4. Key actors fit different profiles

When we combined the results for our three research questions, we noted that there are different categories of knowledge brokers. We identified three different profiles in the schools in our study, which we call: super-traders, transceivers and transmitters.

Super-traders scored highest per school on at least five out of six proportion scores (i.e., incoming ties, outgoing ties, reciprocal ties, intensity incoming ties, intensity outgoing ties, two-way KB). They brokered knowledge about focus, processes, approach, and advantages of the PLC. They used relatively much two-way KB and the most different types of activities to broker the knowledge. We identified five super-traders: Amber, Bob, Carol, Danielle, and Esther. One key actor at each of the schools in this study was a super-trader.

Transceivers (cf. Supovitz et al., 2018) were more often chosen by their colleagues as an interlocutor than they were broadcasting information (higher proportion of incoming ties compared to outgoing ties). This study showed a dichotomy between transceiver types. Plain transceivers (here Andrew, Arthur and Belinda) mainly brokered knowledge related to process and outcomes. They used only one to two different activities, mostly related to knowledge management and thus one-way KB. The exchange and transfer of information stayed rather basic. Advanced transceivers (here Chris, Cecilia, Debbie, and Emily) brokered knowledge related to the PLC's focus and its process and outcomes. They used four or more different activities to broker knowledge. This indicates that they vary more in type of knowledge and the activities used to broker knowledge were more often related to linkage and exchange, which is two-way KB. Because of this difference, we think of them as more advanced. Although their level differed, at least one key actor at each of the schools in this study was a transceiver.

Transmitters (cf. Supovitz et al., 2018) were more often broadcasting information than they were chosen as interlocutor by their colleagues (higher proportion of outgoing ties than incoming ties). Transmitters (here Bryan, Charlotte, Doreen, Evelyn) differed tremendously in the types of knowledge they brokered and the variety of activities they used to broker knowledge. Their common focus was on broadcasting information. At all but one school in this study, one key actor was a transmitter.

5.5. Practical implications

Brokering different types of knowledge (e.g., with regard to the focus and advantages of the PLC) helps to engage the whole school learning community, which is necessary for sustainability (Stoll et al., 2006). Additionally, our results show that more experienced staff members seem to be important for KB. Including one or two mid- or late-career staff members in a PLC might be beneficial for KB and sustainable school improvement. Finally, the activities that were identified in this study shaped the KB processes in five different schools. School staff members can draw from these concrete examples to improve KB at their schools, by incorporating activities related to the different categories.

5.6. Limitations and future research

We acknowledge several limitations of our study. First, we only administered the questionnaire once, so no conclusions could be drawn about stability or change over time.

Previous research showed that central brokers who build trust (Kolleck, 2014) and who concentrate on the focus of the PLC (Hubers et al., 2019) are present at the start of the sustainability trajectory. We showed that further along in the sustainability trajectory, KB is more diffused. Different types of knowledge brokers might be necessary in different phases of the school improvement process. Longitudinal studies in which the social network questionnaire is administered and key actors are interviewed once or twice a year may broaden our knowledge of different phases of sustainability and the key actors in KB processes who help with sustainability. The identified profiles can help in that respect. These profiles can be refined, tested on a larger scale, and in different phases of the sustainability trajectory. This helps to identify key actor profiles necessary for each phase, so that schools can better shape the KB processes for sustainable school improvement.

Second, our research focused on one context: the Dutch context. In this context, school staff members have the freedom to decide what and how they want to teach, and to implement curriculum innovations (OECD, 2008, 2010), which might affect their involvement in the PLC and related KB processes. We did not measure organizational learning culture, although previous research identified its importance for organizational learning (Devos & Verhoeven, 2003). Additionally, the schools in our study differed on several aspects: the level and size of the schools, the type of PLC they used, how long they worked with the PLC, the PLCs composition and the number of staff members that worked with the PLC. Analytical generalizability instead of statistical generalizability is therefore applicable to case studies. Our in-depth and detailed descriptions of the schools allow researchers and school staff members to assess to what extent the results apply to their schools or contexts (Poortman & Schildkamp, 2012). The schools and key actors, within this context, were however similar in the fact that they brokered the same types of knowledge and used the same activities to do so. Studies in other contexts are necessary to develop a more comprehensive understanding of KB processes for sustainable school improvement.

The question why certain PLC participants engage in a lot of KB and become key actors, and others with the same characteristics do not, remains. This is an important question, especially when advising schools on to best select staff members for the PLC. Future studies might therefore focus on key actors' motives and perception of the PLC to find answers to that question. Motives "underpin traits such as enthusiasm, commitment, courage and creativity, all of which are recognized as important qualities for knowledge [brokers]" (Ward, 2017, p. 487), and perception influences willingness to fully engage in the PLC (Van den Boom-Muilenburg et al., 2021; Wolthuis et al., 2020).

In sum, our study highlights who the key actors are, what types of knowledge they broker and how they broker this knowledge at schools that have realized sustainable school improvement with PLCs. The work therewith increases clarity across the field of KB in general, as asked for by Ward (2017), and in education specifically. We therefore built on previous studies: 1) the work of Hubers et al. (2019), by confirming their types of knowledge and extending it by adding new types of knowledge, being 'advantages of working with the PLC' and 'organizational matters'; 2) the work of Farley-Ripple & Grajeda (2020) and Ward et al. (2009), by identifying KB activities that confirm their categories of KB activities; 3) the work of Supovitz et al. (2018), by confirming their broker profiles and extending it by adding a new broker-profile, being 'super-trader'. Additionally, by considering prominence in the social network instead of function in the school, we were able to take the complete picture of activity in schools into account and to fully understand how knowledge travels within the school by considering both degree centrality and betweenness centrality (Rodway et al., 2021). These insights will help researchers with further studying the topic of sustainable school improvement and KB as well as schools in building and improving KB to sustainably work on school improvement with PLCs.

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Declaration of competing interest

The authors declare that they have no conflicts of interest.

Appendix A

In-Depth Description of Activities Related to Knowledge Management Used by Key Actors

School	Key actor	Knowledge management		Written, without artifact	Written, with artifact
		Oral, without artifact	Oral, with artifact		
A	Amber	- In teacher room - During presentation - During department meetings - During school leader meetings	- In department meeting, artifact = Tables with data from student tracking system	–	–
	Andrew	- In teacher room - During presentation	–	–	–
	Arthur	- In teacher room - During presentation	–	–	–
B	Belinda	- In teacher room	–	–	–
	Bryan	- In teacher room	–	–	–
	Bob	- In teacher room - During presentation	–	–	–
C	Carol	- In teacher room - During presentation	- In teacher room, artifact = flyer	- Email - News letter	- Email, artifact = instruction booklet
	Chris	- In teacher room - During presentation - During school leader meetings	–		- Email, artifact = instruction booklet
	Cecilia	- In teacher room - In hallway between lessons - During presentation	–		- Email, artifact = instruction booklet
	Charlotte	- In teacher room - During presentation	- In teacher room, artifact = flyer	- Email - News letter	- Email, artifact = instruction booklet
D	Danielle	- In teacher room - During presentation - During department meetings - During school leader meetings	–		
	Debbie	- During presentation - During department meeting - During school leader meetings	–	- News letter	
	Doreen	- In teacher room - In hallway between lessons - During presentation	–	- Email	- Email, artifact = PLC manual
E	Emily	- In teacher room - In hallway in between lessons - During presentation	–	- Email	- Email, artifact = example observation schemes
	Esther	- In teacher room - In hallway between lessons	–	- Email	
	Evelyn	- During presentation - During department meetings	–	- Email	- Email, artifact = posters (on classroom walls as well)

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Appendix BIn-Depth Description of Activities Related to Linkage and Exchange Used by Key Actors

School	Key actor	Linkage and Exchange				
		Involve school staff members	Provide assistance and support	Make PLC part of school policy	Link school organization and PLC	Organize the PLC in the school
A	Amber	- Ask colleagues for input (e.g., for hypotheses) during a team meeting	- Answer questions about data use	- Add the PLC as a discussion point to the agenda of various meetings - Plan meetings to share PLC-results	- Mention how and why a PLC might help find a solution to an experienced problem and suggest starting a PLC. - Explain the advantages of working with the PLC - Discuss the PLC-results with colleagues who did not participate in the PLC in-depth	- Explain why a colleague can be an asset for the PLC and invite them to participate
	Andrew	–	–	–	–	–
	Arthur	–	–	–	–	–
B	Belinda	–	- Answer questions about specific PLC-steps	–	–	–
	Bryan	–	–	–	- When resistance is expressed, explain the advantages of working with the PLC and how the compensation in time makes it not an extra burden for the teaching job	- Invite staff members to participate in the PLC and follow PLC-related courses
	Bob	- Ask colleagues for input on the next PLC	- Answer questions about the PLC	- Plan meetings to share PLC-results	- Explain the advantages of working with the PLC	–
C	Carol	- Ask colleagues for input on the next PLC and the problem under investigation, by asking the actions they would take based on different situation sketches - Ask colleagues who are experiencing the problem that the PLC is investigating to attend PLC meetings and think along	- Answer questions about data use		- Explain to colleagues what the PLC is investigating and how the results can be beneficial for the school	–
	Chris	–	- Answer questions about data use and the PLC	- Add the PLC as a discussion point to the agenda of various meetings - Plan meetings to share PLC-results	–	–
	Cecilia	- Ask colleagues for input on possible causes of or solutions for the problem under investigation by the PLC - Ask colleagues for their opinion, for example, about the suggested improvement measures	- Answer questions about data use and the PLC	–	- Discuss the PLC-results with colleagues who did not participate in the PLC in-depth	–
	Charlotte	- Share ideas for problems that might be interesting to focus on in future PLCs and ask colleagues for thoughts about these ideas - Ask colleagues that are experiencing the problem that the PLC is investigating to attend PLC meetings and think along	- Answer questions about data use	–	- Discuss the PLC-results with colleagues who did not participate in the PLC in-depth	–
D	Danielle	- Ask colleagues of departments that are not experiencing the problem for input on causes and solutions	- Answer questions about data use - Find someone who can help a colleague with data use	- Add PLC to department meetings plan, so it is discussed at each meeting - Ask about the PLC and what the results mean to the department during formal meetings	- When resistance is expressed, explain the advantages of working with the PLC - Discuss the PLC-results with colleagues who did not participate in the PLC in-depth	- Explain why a colleague can be an asset for the PLC and invite them to participate - Deliberately choose the PLC-composition
	Debbie	–	- Answer questions about data use and the PLC	- Plan schoolwide meetings to present the PLC-results - Add PLC as a formal discussion point to different meeting formats (e.g., department meeting)	–	- Invite colleagues to participate
	Doreen	- Ask colleagues for input on causes or solutions for the problem that is under investigation by the PLC	–	–	- When resistance is expressed, explain the advantages of working with the PLC	–
E	Emily	- Ask colleagues about problems they are experiencing as input for the next PLC.	- Answer questions about the PLC	–	–	–
	Esther			- Add PLC as a formal discussion point to	- When resistance is expressed, explain the advantages of working with the PLC	–

(continued)

School	Key actor	Linkage and Exchange				
		Involve school staff members	Provide assistance and support	Make PLC part of school policy	Link school organization and PLC	Organize the PLC in the school
	Evelyn	- Ask colleagues about problems they are experiencing as input for the next PLC. —	- Answer questions about the PLC —	different meeting formats (e.g., department meeting) - Plan schoolwide meetings to present the PLC-results	- When resistance is expressed, explain the advantages of working with the PLC	- Invite colleagues to participate

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