



Principals' Leadership of Mathematics Teachers' Professional Development

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Leadership has long been recognized for having a significant impact on teacher learning. While research on development programs for mathematics teachers has suggested a change in focus from teachers being passive participants to becoming active learners in practice-based development programs, little is said about how this change in focus affects the principals' role as leaders of teachers' professional development (PD). In response to this, the presented study investigates how a Norwegian school management team facilitates and supports its mathematics teacher's PD in their first year of participation in a particular practice-based development program. Findings from the study show that supporting teachers' PD is easier said than done. The study highlights the importance of building teachers' sense of ownership and having a shared overarching goal for participating in a practice-based development program. Moreover, there must be a structure and a practice for development work at school if a plan for development in practice is to be successfully implemented and fulfill teachers' need for continuous development support. Based on the findings from this study and the use of cultural historical activity theory (CHAT) and the activity system, the article suggests that at least two prerequisites must be present for practice-based development programs to serve as mediating artifacts for teachers' PD. First, the roles involved in the development work must be defined so that the work or goal-directed actions divided between the people in the shared community act towards the same object. Second, the school leader needs support in his work as a leader of teachers' PD.

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INTRODUCTION

In a two-year-long practice-based development program in mathematics, teacher educators and a group of teachers from a number of schools come together five times a year for a daylong, job-embedded professional learning event, driven by teacher educators. The events, called a cycle of enactment and investigation, take place in a genuine school context. Each cycle starts with a discussion based on a pre-read article or a short video vignette of a teaching sequence related to ambitious mathematics teaching. Then the teachers are divided into arranged groups where they plan to carry out an instructional activity together with their supervisor, focusing on how to enact particular practices for ambitious mathematics teaching. One or two of the teachers are responsible for carrying out the instructional activity with a group of real students in an actual classroom context. At the end of the planning sessions, they have a rehearsal where the other teachers act as "students", asking questions that real students might ask. The rehearsal gives the teachers the opportunity to try

out and discuss the teaching strategies and moves they have planned. During the rehearsal and the conduction of the instructional activity, the teachers, as well as the supervisor, can pause the instruction by initiating a teacher time-out that instantly freezes the situation and enables the group to think out loud together in the moment and determine the direction of the further instruction. The cycle ends with a group discussion where the teachers reflect on the conducted instructional activity and the planning process together with the supervisor before briefly preparing for the next upcoming event.

The practice-based development program briefly described above is called the *Mastering ambitious mathematics teaching (MAM) program*, aimed for in-service mathematics teachers in Norway (e.g., Fauskanger & Bjuland, 2019; Wæge & Fauskanger, 2020). The program has been developed and contextualized for the Norwegian situation from the *Learning Teaching in, from, and for Practice (LTP)* project (e.g., Ghouessini, 2017; Kazemi et al., 2016; Lampert et al., 2013). Research on practice-based pedagogy has become increasingly popular within mathematics teacher education and teacher learning over the past 2 decades (e.g., Charalambous & Delaney, 2020). One approach to teachers PD that has become particularly popular and also given an important direction of practice-based PD, is Lesson Study (see Huang & Shimizu, 2016 for a systematic review). Scholars have shown that Lesson Study can improve teachers' knowledge and build productive professional learning communities (e.g., Lewis et al., 2009). Research on practice-based pedagogies has led to an understanding that teaching is a key part of the process of learning to teach (e.g., Ball & Forzani, 2009; Grossman et al., 2009; Lampert, 2010).

Teachers' professional development (PD) is essential if classroom practice is to be changed (Borko, 2004), and is an ongoing process in which teachers' continuous growth depends on their own effort (Pokhrel & Behera, 2016). Research has also indicated that meaningful support from school principals is crucial in promoting teacher learning through PD (Akiba et al., 2015; King & Stevenson, 2017; Silva, Amante & Margoda, 2017). The principal can support teacher learning by creating a learning culture, shaping learning opportunities and providing resources, time, encouragement, and monitoring (Desimone, 2009). School leaders need to acknowledge their role as facilitators for teachers' learning and ensure that proper learning conditions are established to create a culture of learning at the school (Walker, 2007).

Research on practice-based development and the school leaders' role in teachers' learning and development has received much attention. However, little of this attention has been devoted to the principals' role in leading mathematics teachers' learning as they participate in practice-based development programs that are job-embedded. The study presented in this article aimed to investigate the relations between a principal's leadership and mathematics teacher's participation in a PD by examining a Norwegian lower secondary school's first year of participation in the MAM program (see description below). This article focuses on school managements' role in terms of how they support and facilitate in-service mathematics teachers' PD when they participate in a job-

embedded practice-based development program such as the MAM program. While focusing on the school leaders' role, I have used Cultural Historical Activity Theory (CHAT) and the activity system (Engeström, 1987, 1999, 2001) as the theoretical framework for analyzing and discussing the findings. The activity system contributes to describing and analyzing activities within an organization, such as teachers' PD in a school, and can thus be used as a tool for discovering aspects that have development potential (Postholm M. B., 2020). The study presented in this article is driven by the research question:

How does school management support and facilitate mathematics teachers' professional development as they participate in a practice-based development program?

The analysis and discussion of the findings related to the research question will lead to further discussions of possible opportunities for change and development in the frame of CHAT and the activity system. By using the activity system as the unit of analysis, I will identify tensions and contradictions that can be a starting point for change and development. In the following, I will start by presenting related research before elaborating on CHAT and the activity system, and the context of the study. Then I will present a description of the method, and explain how the data was collected and analyzed. Finally, I will present and discuss the findings prior to making my concluding remarks.

RELATED RESEARCH

Teacher Professional Development

Several researchers claim that Teacher PD is the key to successful school reform and student learning (Desimone, 2009). It is understood as activities that improve teachers' knowledge, skills, and attitudes towards teaching practices (OECD, 2014). These activities can have various forms and have traditionally been identified as official events, such as conferences, workshops, and degree programs (Burns & Darling-Hammond 2014). However, researchers have suggested that out-of-school programs are limited in their connection between teacher learning and the actual practices in school (Villegas-Reimers, 2003; Desimone, 2009). This idea is supported by an extensive body of research arguing that teacher's PD should be connected to and contextualized within practice, and in that sense it should enable teachers to develop their knowledge and ability to use new ideas (e.g., Ball & Bass, 2003; Ball & Even, 2009; Kennedy, 2016). Teacher PD should also treat teachers as active students, be maintained over time, and open for collaborative participation (Desimone, 2009) which further facilitates teacher collaboration that is assumed by researchers to contribute to PD and instructional improvement (DuFour and Fullan, 2012).

Watson (2015) argues that teachers' PD usually begins with an understanding of teachers' needs at their own school and in their classroom, and the effects of any PD program depend heavily on teachers' motivation to learn and to change their practice (Kennedy, 2016). Furthermore, Engeström and Sannino (2010) have found that the development work must be "owned" by the practitioners and therefore based on their development needs.

This means that the teachers must take part in the development work right from the beginning and be acknowledged as the heart of the decision-making around change, which is a key principle in understanding, engaging, and developing ownership in adult learning (Knowles et al., 2005). The development effort is, in this way, made together with the teachers instead of being designed as doing things to teachers, an approach that aligns with what researchers have found in successful teacher PD (Clarke & Hollingsworth, 2002). From a contrary point of view, it is argued that PD initiated by an outside member of the community suggests that problems identified externally are beyond the capability of the teachers within a given community to solve and can further promote a de-professionalization of the teacher (Roseler & Dentzau, 2013).

Furthermore, Timperley et al. (2007) found that teachers should at least understand the purpose of the work and why they should attempt to move their practice in that direction. Time must therefore be allotted for the teachers to develop an understanding of the goal and why they should act upon it in the start-up phase of the development work (Postholm, 2008; Postholm, M. B. 2020). Moreover, the work of teachers' PD is a matter of what to develop and how to develop it, and research shows that the focus on content and the process must go hand-in-hand and be integrated in the development work (Postholm et al., 2013).

Leadership for Teachers' Learning

It is widely acknowledged that leadership can be practiced in a way that might have a significant impact on promoting and sustaining change (Fullan et al., 2005). Research on educational management and leadership concludes that school principals possess an important position that can have substantial influence on teachers' learning (Leithwood et al., 2020). For instance, findings from a study in England indicated that PD for school improvement can result in real change if the school leader understands its potential (Opfer et al., 2011). The principal can contribute to creating a learning environment by exercising a school leadership practice that helps teachers to identify their development needs and enhances the implementation of new learning (Thoonen et al., 2016). A leadership practice can involve several leaders who interact with each other and the actual learning situations (Spillane, 2005). Spillane (2005) argues that "structures, routines and tools are the means through which people act" (p. 147). Furthermore, Darling-Hammond and Richardson (2009) argue that there needs to be a plan for teacher PD, and Earley and Bubb (2004, p. 80) state that "professional development does not just happen—it has to be managed and led," and has to be supported and encouraged by the leaders (Silva et al., 2017). Research shows that teachers need continuous development support in their PD work (King & Stevenson, 2017), and that it is the school leaders' task to arrange for the teachers' learning in schools (Elmore, 2000).

Although leading teachers' PD is often considered to lie within the school leaders' role, research shows that teachers can be development leaders in their own schools. Grootenboer and Hardy (2017) claim that the leading of teachers' PD needs to be a shared enterprise as the task is often too much to handle for

one person alone, a notion that is supported by Postholm (2019), who argues that the work with developmental processes should be distributed between different leaders, or between leaders and teachers. To do this, the principals must have the courage to let go of leadership and be willing to place their trust in their teachers' beliefs, values, and judgements, which is considered to be the challenge for leadership (European Commission, 2010). Building professional trust is important when establishing a productive learning environment for the teachers (Liu et al., 2016), and can furthermore allow teacher leadership to flourish (Smylie et al., 2007). However, certain conditions must be taken into account if teacher leadership is to be fruitful. For instance, Birky et al. (2006) argue that school administrators must encourage and motivate their teachers to be effective leaders through their words and actions. The principal can therefore influence teacher leaders' motivation to exercise their leadership role effectively through his or her style and actions.

CULTURAL HISTORICAL ACTIVITY THEORY

CHAT was developed by Leont'ev (1978, 1981) on the basis of Vygotsky's work, which implies that learning and development are rooted in socio-cultural theory (Wertsch, 1981). Leont'ev (1981) says that "the object is the true motive" (p. 59) for people's actions. Teachers, school leaders, or other educators should therefore share a collective motive to act on the object, or at least know about the object they aim to develop their practice towards. The object can in this way become "invested with meaning and motivating power" (Sannino et al., 2016, p. 602), and the teachers' motivation should therefore be built into the object because it is their practice and needs that serve as the starting point. Engeström (1987) expanded on Vygotsky's individual definition of the zone of proximal development to include a collectivist and social perspective, seeing how the activity can develop a collective, such as a team of teachers and a school as a whole, into a new form of social activity. He defines this as follows: "It is the distance between the present everyday actions of the individuals and the historically new form of the societal activity that can be collectively generated" (p. 174).

The Activity System

As explained above, CHAT is the result of Leont'ev's expansion on Vygotsky's work. The activity system (shown in **Figure 1** below) is a graphic development of the activity theory (Engeström, 1987, 1999, 2001; Engeström and Miettinen, 1999) and is therefore formed on the basis of CHAT. This system, considered to be a unit of analysis of human activity, consists of the seven factors: subject, mediating artifacts, object, outcome, rules, community, and division of labour (Engeström, 1987). These factors are related and thus have a mutual impact on each other, thus forming a dynamic system where a change in one factor will influence another in the system and also the system as a whole (see **Figure 1** below).

The acting subject refers to a person or a group of people from whose viewpoint the analysis of the activity system is conducted

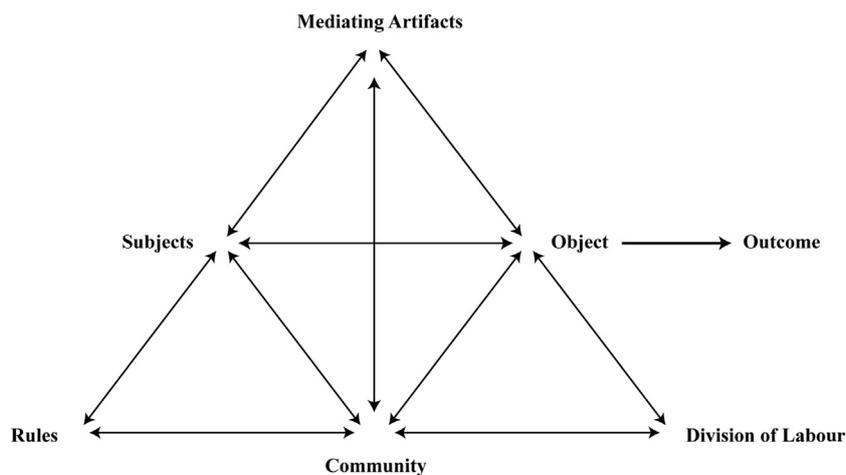


FIGURE 1 | The complete activity system (Engeström, 1987,1999,2001).

(Engeström, 1999). A team of teachers can thus be an active subject in the system that utilizes cultural mediating artifacts to move practice towards the object, here defined as an overall goal. Mediating artifacts can comprise such physical artifacts as smartboards, tablets, books, or pencils, but also language and even a development program which a group of teachers participates in, as it can be defined as an aid or a thinking tool (Postholm M. B., 2020) that aims to support the development of their teaching. How the subject has moved towards the object and the desired result is shown as the outcome in the system. In the context of teachers' PD, the outcome might also include students' learning if the attention is on the teacher's classroom practice. The three remaining factors represent the context in which the activity is carried out and may determine the premises and possible restrictions for the subject's goal-directed actions towards the object (Engeström, 1987). The context is therefore not just a surrounding element but rather interwoven in the actions. The community refers to the people who share the same object, as in relation to how the teachers' PD can refer to the actual teachers and leaders who aim to facilitate and support the development process. The people in the shared community act within a set of rules such as norms and conventions that guide the actions in the activity system. The conducted work or goal-directed actions are divided between the people in the shared community and are described as the division of labour. Tensions or contradictions between the various factors in this activity system may occur and are, according to Engeström and Miettinen (1999), the basis and thus the starting point for change and development.

THE MAM PROGRAM AND THE CONTEXT OF THE STUDY

MAM is a PD program for in-service mathematics teachers that aims to promote opportunities for learning to enact the principles, practices, and mathematical knowledge entailed in ambitious mathematics teaching in an adaptive manner (Fauskanger & Bjuland, 2019; Wæge & Fauskanger, 2020). As stated above, the

MAM program has been developed and contextualized on the basis of the LTP project (e.g., Ghouessini, 2017; Kazemi et al., 2016; Lampert et al., 2013) to fit the Norwegian situation. Whereas the LTP project originally was developed to support teacher students to enact ambitious mathematics teaching practices (Lampert 2010; Lampert et al., 2013), the MAM program attempts to adapt this pedagogy of ambitious mathematics teaching for in-service mathematics teachers' PD (Fauskanger & Bjuland, 2019; Wæge & Fauskanger, 2020). The core of the MAM program is to engage teachers through the daylong job-embedded PD events called *cycles of enactment and investigation* for PD (e.g., Lampert et al., 2013), earlier introduced in a vignette. Each cycle focuses on one instructional activity and through their work in these cycles the participating teachers will engage with a set of instructional activities during the program. The cycles include the six stages: preparation, collective analysis, co-planning, rehearsal, classroom co-enactment, and collective analysis. The teachers work together in groups, and are planning, rehearsing, enacting, and debriefing instruction throughout these six stages¹.

The MAM program is modelled on research of effective forms of PD that are argued to be sustainable over time, and that build systematic support and provide opportunities for active learning (e.g., Putnam and Borko, 2000; Desimone, 2009). Furthermore, the MAM program is informed by theory on teachers' collective learning in a community of practice (Wenger, 1998). The circle of enactment and investigation provides opportunities for the teachers to actively take part in mutual processes of negotiation of meaning to create a joint enterprise (Wegner, 1998). Moreover, the teachers are invited to engage in collective exploration, observation, and reflection by using the instructional activities as a common tool, guided by teacher educators (Wæge & Fauskanger, 2020). Thus, in addition to promoting opportunities to learn to enact the principles, practices, and mathematical knowledge entailed in ambitious mathematics teaching, the MAM program can be considered to offer a model for teachers' PD.

In addition to two informative start-up sessions, this program was planned to have a duration of 2 years, starting in the fall of

2019 and consisting of 12 sessions held at one of the participating schools. A full cycle of enactment and investigation was planned for ten of the sessions, five each year. The last two sessions were reserved for reflection, one at the end of each school year. The two start-up sessions were held prior to the end of the previous school year and were used to inform the participating teachers and school leaders about the program. Teachers from eleven primary schools in the same district also participated in the start-up sessions as they were attending a MAM program for primary mathematics teachers. The teachers were introduced to the practices and principles of ambitious teaching and the instructional activities.

The context of this study is a Norwegian lower secondary school with 330 students, seven mathematics teachers and a school leader team consisting of the school principal and a vice-principal. The school is multicultural with students of different ethnicities. The school participated in the MAM program together with three other lower secondary schools in the same district. This study followed the school's first year of participation.

METHODOLOGY

To address the research question presented in this article a qualitative interview study (Kvale and Brinkmann, 2015) was conducted at one of the lower secondary schools that was participating in the MAM program in Norway. All the participating lower secondary schools were asked to take part in the research study, and three of the four schools volunteered. To answer the research question and determine what the school managements' decisions concerning the support and facilitation of the mathematics teachers' PD were all about, I found it necessary to conduct a thorough investigation and cultivate this within the research context (Walcott, 2008). The three schools that volunteered were relatively similar in the number of mathematics teachers and number of students. However, two of the schools had been through several changes in school management in recent years. As I did not want to risk a major change in the school management during the period of the study, I selected the school that had had the most stable school management in

recent years. Structures and practices for leadership and developmental work are usually created prior to or at the beginning of a development process, and the start-up phase is argued to have an impact on learning and enduring change (Postholm, 2008, 2020). Thus, the study was conducted during the school's first year of participation. The informants in the study have been selected through purposeful sampling (Creswell, 2013) and are: five mathematics teachers, the school principal and the vice-principal, working at a lower secondary school.

Data Collection

The data material in this study has mainly been collected from four focus-group interviews (Kamberelis and Dimitriadis, 2011). The five teachers participated in two of the interviews, the first conducted before the start of the project in the fall of 2019, and the second in the fall of 2020. The other two focus-group interviews were conducted with the principal and vice-principal, the first conducted before the start of the project, fall 2019, and the second in the spring of 2020. Data material was also collected from three follow-up interviews with the principal and vice-principal to clarify concepts. All the four focus-group interviews were conducted as a conversation to comply with Brinkmann and Kvale's (2015) claim that "knowledge is constructed in the interaction between the interviewer and the interviewee" (p. 4), but with a clear focus on pre-prepared questions related to the research question. The interview guides are presented in **Tables 1–4** below. This type of conversation also provides the interviewees with the opportunity to bring forward interesting aspects or themes the researcher did not think of before the interview. I acted as a moderator (Chrzanowska, 2002) throughout the interviews by asking questions to encourage dialog between the participants. All the focus-group interviews were audio-recorded and conducted with the use of a digital communication program due to COVID-19 restrictions.

Data Analysis

The constant comparative analysis method (Corbin & Strauss, 2008; Straus and Corbin, 1990, 1998) was used to structure and analyze the data material in this study. The transcription work

TABLE 1 | Structure of the focus-group interview guide for the school management, fall 2019.

	Questions
1	How is the school management organized in relation to the MAM project?
2	What support do you find the mathematics teachers' need to be able to learn together?
3	How would you describe school management's role as a facilitator for mathematics teachers' professional development?
4	Can you give a specific description of how you facilitate for mathematics teachers' professional development?
5	How is time for development work structured at your school?
6	How would you describe the mathematics teachers' need to develop their knowledge about teaching and teaching practice?
7	How do you assume the mathematics teachers perceive the school's leadership of their development work?
8	How do you understand the MAM program, and how do you assume the program will influence the participating mathematics teachers?
9	What do you think the mathematics teachers will learn through their participation in the MAM program?

TABLE 2 | Structure of the focus-group interview guide for the school management, spring 2020.

Questions	
1	How has the school management been organized in relation to the MAM program?
2	In what way have you supported the mathematics teachers in their work with the MAM program?
3	Can you describe your role as facilitators for the mathematics teachers' professional development this last year?
4	How was the time for development work structured this last school year?
5	How would you describe the mathematics teachers' need to develop their knowledge about teaching and teaching practice?
6	How do you assume the mathematics teachers perceive the school's leadership of their development work?
7	What are your perceptions or experiences of the MAM program halfway through the period?
8	How do you assume that the MAM program has influenced the participating mathematics teachers?
9	What do you think the mathematics teachers have learned through their first year of participation in the MAM program?

TABLE 3 | Structure of the focus-group interview guide for the mathematics teachers, fall 2019.

Questions	
1	In your opinion, how does the principal, or school management, facilitate for your development of knowledge about teaching and teaching practice in mathematics?
2	How do you perceive the development work in mathematics at your own school?
3	What are your opportunities for collaboration in the school, and what occurs during these meetings?
4	Do you find that the collaboration contributes to your development of knowledge about teaching and teaching practice in mathematics?

TABLE 4 | Structure of the focus-group interview guide for the mathematics teachers, fall 2020.

Questions	
1	What is, or was, your perception of the overall goal of the MAM program?
2	What is your experience of school managements' facilitation of your development work with the MAM program?
3	How motivated were you for participating in the MAM program?
4	How did you find the start-up phase of the MAM program?
5	What were your opportunities for collaboration in connection with the MAM project, and what did you do during these meetings?
6	Do you find that the collaboration contributed to your development of knowledge about teaching and teaching practice in mathematics?

commenced immediately after the interview ended. Then the transcriptions were carefully scrutinized and organized into smaller sections and given codes (Straus and Corbin, 1990, 1998). Using an abductive approach in this process (Alvesson & Sköldbberg, 2009), I was looking for descriptions that could be related to the research question. The interviews were treated separately, but with an attention to look for connections between them. I used related theory and my own experiences as a reflecting tool when trying to understand the informant's utterances from their point of view. I thereafter examined the data material for differences and similarities to allow subtle discrimination and differentiation between the categories (Strauss and Corbin, 1998). As relevant categories emerged, the remaining sections were examined to see if the relevant categories were presented. Four key points that emerged during the open coding process (Straus and Corbin, 1990, 1998) became my main categories:

- Lack of ownership
- Motive
- Organizing and supporting teachers' learning

- The teachers' experiences of school management support

To define and specify the categories, the sub-categories were situated within the main categories by asking questions such as why, when, and under which conditions did the categories materialize (Straus and Corbin, 1990, 1998). The data material was also mirrored with the literature relating to the research question. This initial analysis used the constant comparative analysis method to create the scale for further analysis (Charmaz, 2014). Based on this initial analysis and discussion of these findings, I have used CHAT and the activity system to identify tensions and contradictions that can be the starting point for change and development.

Ethical Considerations and Quality Assurance

The study presented in this article has been approved by the Norwegian Centre for Research Data (NSD) and follows the ethical principles laid down by the Norwegian Ethical Research Committee (NESH, 2006). The participants in the study signed a

consent form based on informed consent in accordance with the NSD guidelines. They were also guaranteed full confidentiality and anonymity (NESH, 2006). Neither the school nor the participants are named, but rather referred to as teacher, principal, or vice-principal. The participants were also informed that they could withdraw from the study at any time without further explanation (NESH, 2006; Creswell, 2013).

The quality of this study was ensured through member-checking (Lincoln & Guba, 1985). Although the descriptions and analysis presented in this article are only connected to the teachers and school management from one specific school, the findings from this study may have importance beyond its immediate context if the reader is willing to have a creative and imaginative approach (Geertz, 1973), transforming it into a thinking tool (Gudmundsdottir 2001). Thus, hopefully, the findings from this study can contribute knowledge and considerations to similar situations and contexts.

FINDINGS

The findings are presented as extracts from the focus group-interviews and follow-up interviews. The developed main categories structure the presentation of the findings.

Lack of Ownership

The interviews with the school leader group revealed that the MAM program was initiated by the school owner (the local education authority) in the district. The principal stated:

When we agreed to join the MAM program, one of the prerequisites was that we should be able to continue our work developing a more inquiry-based mathematics teaching. [...] on those grounds, a decision was made over our heads to create collective teacher development work in mathematics for several schools in the district, which was reached together between our leader and the Norwegian Centre for Mathematics Education. The development work was submitted to us, and at that point there was no actual choice about whether to participate or not. And then it was presented to us that this is how it's going to be, the program looked good, so we decided to participate. But at this point we did not have any dialog with our teachers about what they actually wanted or needed to improve in this process.

Later he added:

The decision was taken over our heads [...] what I felt that we could choose was the number of participants.

Although the teachers expressed diminishing motivation, they claimed they were open-minded and entered the program with a positive attitude. The teachers said:

Teacher 1: To sum up, we may not have been the most motivated people.

Teacher 2: We were skeptical, but I don't feel that we were negative.

Teacher 1: No.

Teacher 2: It was more like "what is this?". No, we weren't the most top-motivated people, but we weren't at the bottom either.

Teacher 3: Our motivation level sank during the period.

Motive

The school management team stated that they wanted the teachers to develop how they could learn together. The principal said:

What I mainly hope the teachers learn is how to learn together. That means that the MAM program is first of all about how we can work with the professional learning community at school, more than the teachers learning a specific teaching method in the classroom. Because if we as a school learn how to best learn together, we can in some way use what we have learned in the MAM program to further develop other things we need to learn.

When the mathematics teachers were asked about their motive for attending the MAM program, they answered (the excerpt below starts after a 5-s pause):

Teacher 1: Pass.

Everyone laughs.

Teacher 2: Well. . .

Teacher 3: Well, indeed.

Teacher 1: It became a bit vague, developing the quality of mathematics teaching. We're supposed to get better at teaching, but that's in a way the purpose of all courses.

Teacher 2: I felt that we should get better at teaching in a way that activates the students more. That we should become better at having mathematical conversations in the classroom and using the kind of tasks that we could present in a different way than explaining from the blackboard, or not in a way that many would call traditional teaching. Exploring new methods that should activate the students. To improve these things and practice them throughout this project. At least that's how I interpreted it.

Teacher 4: That was also probably what became decisive for us, that we didn't quite see where we were going with the project. Well, it's quite clear that the goal was in many ways as you say, "active student learning", and methods to achieve it, but I felt the course itself was not always characterized as being useful for that purpose. So, I didn't quite understand what the overall goal was here. I found that difficult to catch.

Organizing and Supporting Teachers' Learning

When school management was asked how they planned to organize the teachers' PD, the principal said:

I found it natural to delegate the work of supervising the development work with the mathematics teachers to the vice-principal. He's a former mathematics teacher and thus has a special competence which will probably give him an advantage when working with the teachers. So, basically, the vice-principal is the one coordinating the development work, together with a teacher-coordinator in mathematics.

Although the principal delegated the main responsibility to the vice-principal, he stated that he was planning to participate in the sessions as much as he could, and that it was crucial that he was also involved in the teachers' development. He stated:

I'm pretty sure that it's crucial that we're both equally up-to-date on the content of the project, and what's going on here at the school concerning the teaching of our teachers if we're going to succeed in this project.[...] It's crucial for all types of development projects that the school management team has good information about what's going on so that we can be part of the process together with the teachers. I think the leaders' participation is crucial. It might be easy to delegate or think that the teachers can do this on their own, but if it really is to mean anything, we also have to show the teachers that this is important to us. So, we have to prioritize our time, focus on this because we believe in it.

The school leader explained that they gave the mathematics teachers designated time to work on the development program. The principal said:

...One of the mathematics teachers has been given earmarked time to coordinate the collaboration between the mathematics teachers. They have also been given time for a two-hour collaboration meeting between the sessions, both to immerse themselves in the content and to work with "homework" that is given at the sessions...

The vice-principal added:

...and facilitated for the teachers to have the opportunity to participate in the courses. There are teachers who are made available for the work, and the financial framework for the teachers to participate has been arranged, etc.

In the focus-group interview with school management after the first year of participation in the program, they reflected on the work they had done to support and facilitate the teachers' development. The principal said:

Our participation is to a great extent lacking, both at the sessions and between them. So, the development work has not been led by us other than organizing the use of time [...] The plan was that the vice-principal should participate in the discussions at the sessions together with the teachers. But he had to spend the time organizing

things like coffee, lunch, supplying teachers, making students available for the lessons, instead of participating.

They maintain that it would have been better if school management had participated in the development program together with the teachers as a part of the program's participation group. The principal added:

The situation could clearly be different if we, school management, participated in the sessions. If so, we would have picked up some of the feedback the teachers are giving us now, and we could have done something at an earlier stage. Perhaps we also could have managed to increase their motivation and "seen" the teachers better.

Furthermore, the principal also reflected on challenges related directly to the MAM program, he stated:

It's easy to be wise after the fact, but what I now see as a big challenge with the whole program is that it has become "one-size-fits-all" [...] I don't feel I have a real impact on either the content or the organization because it has to go this one way. [...] It's the same series of courses for all the participating secondary schools, but I think we would have succeeded better if there were opportunities to make adjustments in the organization and content in relation to each school's needs.

Later in the interview he added:

I experience this as top-down governed. [...] I have no control over this education, and it's a difficult situation to experience for a leader. I don't know who the owner of the project is and who makes the decisions ... I don't know.

The Teachers' Experiences of School Management Support

However, the teachers did not experience school management as being absent from their development process but were rather satisfied with the job it had done in supporting and facilitating their PD. One of the teachers said:

Teacher 1: [...] They have not been negative to the course. I think they just really hoped that we would be satisfied. They have been very good at listening to us when we have provided input. So, in my opinion, I think they have been very accommodating and done what they can. [...] But they may not have planned for us to work a lot with this besides the sessions, but we have not asked for it either as we may not have really wanted to.

Another teacher adds:

Yes, that is more or less true, and as you say said, if we had been super enthusiastic, they might also have become more engaged and given us even more time.

A third teacher adds:

Well, when we have had such meetings and math meetings for the math teachers at the whole school, we have been told to discuss things such as “what are we going to do next with MAM”, “how are we going to work with it?”. That is, they have engaged in it and made sure that we don’t forget. So, I have nothing to say about that.

The teachers reflected on the work they were supposed to do between the sessions, which was to read an article. One teacher said:

Honestly, I don’t know. It feels like it’s homework, something I have to do, but is this really something I need? That’s what I feel.

Another teacher adds:

To me it was a little like that I forgot it a little, and then I remembered it, we got a reminder by e-mail 1 week before the session or something like that, and then it kind of sat there so I read it maybe the night before or in the morning before the session. I didn’t prioritize it because as a teacher there are so many things to prioritize and remember, so many conversations to have, so it was never on the top of my priority list. So, it was only read right before the session.

ANALYSIS AND DISCUSSION

In this section I will first analyse and discuss how school management has supported and facilitated the mathematics teachers’ PD in their first year of participation in the MAM program. Then I will use CHAT and the activity system to further analyze and discuss tensions and contradictions that can serve as a starting point for future PD. The presented data are analyzed and discussed across the main categories.

A Lack of Ownership and Joint Motive

The interviews with the informants revealed that the decision to work with the MAM program as a development project for the mathematics teachers was made solely by the school owner. The school was not invited to take part and therefore was not included in the process of finding a suitable development program for the mathematics teachers. Furthermore, school management did not have a dialog with the teachers as to what they actually wanted or needed to improve their classroom practice. Thus, the decision to participate in the MAM program was made on the basis of what was presented, which school management believed aligned with their conditions for participating, and not with the teachers’ actual needs. Watson (2015) argues that teacher PD should be based on the teachers’ needs at their school and in their classroom. As the school was not included in the process of deciding what development program to attend, there is also reason to believe that they were deprived of the opportunity to determine how the program fit with their development needs.

Omitting mathematics teachers from such processes can restrain their learning and development, as acknowledging the teachers as the heart of decision-making around change is a key principle in understanding, engaging, and developing ownership in adult learning (Knowles et al., 2005). A development program chosen and decided by the school owner can of course be both relevant and based on the teacher’s needs. However, this way of making decisions *for* the school and the teachers on the basis of what someone else thinks is best for them, instead of making decisions *together* with the teachers, is the opposite of what researchers have found to be the underpinning of successful teacher PD (Clarke & Hollingsworth, 2002). This can rather be characterized as a traditional top-down approach to teacher PD which can be argued as de-professionalizing the teacher (Roseler & Dentzau, 2013).

There appears to be a mismatch in motives between the principal and the teachers. The principal is more concerned about how the MAM program can contribute to developing the learning community where the teachers in the whole school can learn together, not just the mathematics teachers, than the mathematics teachers’ development of teaching methods. There are good reasons to focus on such a goal. The MAM program draws on research on effective forms of PD, and has a collective perspective on learning where the teachers take part in mutual processes of negotiation of meaning to create a joint enterprise in a community of practice (Wenger, 1998). It is far from certain that the principal’s statement is based on Wenger’s ideas. Nevertheless, it shows that the MAM program can contribute to achieving the principal’s main goal for participating, which is for the teachers to develop collective learning processes, and, furthermore, that such a focus on PD has the potential to improve the school, which can result in real change as the overarching goal (Opfer et al., 2011). The teachers seemed uncertain as to what the goal of the MAM program was and what they were supposed to learn through their participation. They hesitated to answer questions on this, and it did not seem that there was a clear and common understanding of what they were to develop through their participation in the program. According to Timperley et al. (2007), the participating teachers should at least have developed an understanding of the purpose of the development work, and moreover why they should attempt to move their practice towards the object of the work. The uncertainty the teachers show about the motive of the development work, and the fact that they and the principal have different motives, might be the consequence of not allotting enough time in the start-up phase to develop a shared overarching goal for participating in the MAM program.

The effects of any PD program depend heavily on teachers’ motivation to learn and to change their practice (Kennedy, 2016). The presented data show that the teachers were not highly motivated to participate in the MAM program from the beginning, and that the motivation also decreased during the program period. The teachers’ satisfaction with school management’s support and facilitation, despite their absence, and the teachers’ lack of initiative to spend time on the MAM program beyond the sessions can also be understood as a sign of a lack of motivation. This is not surprising if we see this in terms of

Leont'ev (1981) statement that “the object is the true motive” (p. 59) for people’s actions. The teachers’ have to share a collective motive for acting on the object if it is to be “invested with meaning and motivating power” (Sannino et al., 2016). As the teachers’ needs did not serve as a starting point for the development work, and as there was a lack of a common understanding of the purpose, it appears that their motivation was not built into the object. Also, the teachers said they did not ask for more time and support to work with the MAM program outside the meetings, which indicates a lack of initiative and commitment (Sannino et al., 2016).

A Plan for Organizing and Supporting Teacher Learning—in Word but not in Deed

The principal had a clear strategy for how to lead and organize the teachers’ PD as they participated in the MAM program, a strategy that included delegating responsibility to the vice-principal and a mathematics-subject coordinator. Leading teachers’ PD can often be too much to handle for the principal alone, and the principal’s way of treating leadership as a shared enterprise (Grootenboer & Hardy, 2017) might be useful in trying to avoid this challenge. Delegating the management of organizational issues and supervision of the teachers’ participation to the vice-principal is also a way to build trust by acknowledging his competence as a former mathematics teacher. The same acknowledgment was given to one of the mathematics teachers who was assigned the task of coordinating the teachers’ day-to-day job related to the development work. Building professional trust is important for establishing a productive learning environment for the teachers (Liu et al., 2016), and for giving teacher leadership the opportunity to flourish (Smylie et al., 2007). The principal’s strategy also included a plan for facilitating the teachers’ development work by providing them with designated time in the timetable, which enabled them to collaborate between the sessions. Teacher collaboration is assumed by researchers to contribute to PD and instructional improvement (DuFour and Fullan, 2012), and making sufficient time available for the participating teachers to collaborate is an important feature in teacher learning (Desimone, 2009). The principal furthermore planned to have an overview and engage directly in the teachers’ learning process, not by controlling, but by keeping up-to-date on what the teachers could learn in the program and getting involved in their development process. Despite a messy start with this development work, it seems that the school, in accordance with what Darling-Hammond and Richardson (2009) maintain, had a plan for organizing and supporting the mathematics teachers’ PD, both within and alongside their participation in the MAM program.

Nevertheless, a plan must be implemented in practice to fulfil its intention, and the data show that the plan school management produced was only partly followed in practice. The principal delegated the work and designated time for the teachers to collaborate and reflect on their learning, which indeed is a way to support teachers’ PD (King & Stevenson, 2017). However, organization is not sufficient on its own, as teachers need continuous development support (King & Stevenson, 2017).

Although the principal had planned for the teachers to use the designated time to immerse themselves in the content of the program and do the homework, which involved reading and discussing an article, the teachers perceived this in another way. They argued there were not facilitated any work related to the MAM program besides the sessions, and they did not perceive that the collaboration meetings between these sessions should be used to read the given article. Thus, a common understanding had not been established between the teachers and school management about what the allocated time was intended for. Furthermore, Birky et al. (2006) maintain that school administrators must encourage and motivate their teachers to be effective leaders through their words and actions if the teacher leadership is to be fruitful. As the principal and vice-principal were not present at the sessions or the collaboration meetings, the teachers’ statements indicate that the teacher who was assigned the responsibility of coordinating the teachers’ day-to-day work with their participation was left alone and did not receive sufficient support from school management. Spillane (2005, p. 147) argues that “structures, routines and tools are the means through which people act”. School management could have interacted on aspects of the teachers’ learning situations, including using a variety of tools, routines, and structures (Spillane, 2005), but such a practice did not seem to be established in this case.

The principal says he experienced a lack of control over the MAM program and described it as a “one-size-fits-all” project with no opportunities to make ongoing adjustments in line with the school’s needs, both organizationally and in terms of subject matter. The importance of the development work being closely linked to the participants’ context is well documented, especially when it comes to school-based development (e.g., Postholm, 2008, 2020; Smith & Landsay, 2016). Furthermore, Engeström and Sannino (2010) maintain that the development work must be owned by the practitioners, which means it must be based on their development needs. Although the MAM program is a job-embedded teacher development program that takes place in practice at one of the participating schools, it is not a school project. Teachers from several schools are participating in the program together, and the possibilities for making adjustments based on all the schools’ needs are therefore limited. The MAM program is a PD program that aims to promote opportunities to develop ambitious mathematics teaching (e.g., Fauskanger & Bjuland, 2019; Wæge & Fauskanger, 2020), which the school participated in to further develop inquiry-based teaching. It is of course important to remember that the school was omitted from the process of finding a suitable development program for the mathematics teachers. Nevertheless, it seems that the principal was more concerned with how to adjust or change the MAM program rather than how to arrange and support the teachers’ participation in the program so that it could contribute to improving their classroom practices.

As Earley and Bubb maintain (2004, p. 80), “professional development does not just happen—it has to be managed and led,” and needs to be supported and encouraged by the leaders (Silva et al., 2017). The analysis in this study shows that the principal paid too little attention to leading and supporting the

teachers' PD in building a structure for the development work, as management ended up only organizing the teachers' PD in time and place. Moreover, the teachers did not manage to use the allocated collaboration time to create a learning community where they could develop their understanding of the core practices and principals of ambitious teaching. In other words, without more detailed arrangement and support from school management, the teachers did not manage to create a "historical new form of societal activity that was collectively generated" (Engeström, 1987, p. 174).

The MAM Program as a Mediating Artifact

As described above, the MAM program is here defined as a mediating artifact meant to function as an aid for the teachers to develop their classroom practice. However, the findings reveal contradictions within and tensions between the factors in the activity system (Engeström, 1987, 1999, 2001). I have already pointed out that the teachers do not feel that they "owned" the development work, and that there was a mismatch in the motive for participating in the MAM program between the principal and the teachers. In other words, there is a contradiction within the community in the activity system as to how the MAM program should serve as a mediating artifact. Developing a shared motive to act on the object can therefore be a reasonable starting point for this school's change and development (Engeström and Miettinen, 1999; Leont'ev, 1981). To accomplish this, time and resources must be allocated in the start-up phase for the teachers to identify with the topic for the PD work (Postholm, 2008; Postholm, M. B. 2020). This process must also be led and facilitated by the school leader. As the principal possess an important position that can have a substantial influence on teachers' learning (Leithwood et al., 2019), the responsibility lies within his role to create a learning environment that helps teachers to identify their development needs and enhance the implementation of new learning (Thoonen et al., 2011; Vanblaere & Devos, 2016). Through such a process, the teachers' motivation would be built into the object because their practice and needs serve as the starting point for the development work (Sannino et al., 2016). Also, restrained development work due to a lack of motivation on the part of the teachers can be avoided.

The findings reveal that the participants, both school management and the teachers, struggled to understand how to benefit from their participation in the MAM program in the mathematics teachers' development work. This could be understood as a tension between the community and the MAM program as a mediating artifact. Bearing in mind that the teachers' and school management's motive for participating in the MAM program differed when it came to content and process, they tried to understand how to benefit from the program from different points of views. However, as research shows that the focus on content and process must go hand-in-hand and be integrated into the development work (Postholm et al., 2013), I would argue that both motives could be built into the object in this activity system, and furthermore that the MAM program could serve them both. The program provides mathematics teachers with the opportunity to develop ambitious mathematics teaching through the cycle of

enactment and investigation (Lampert et al., 2013), together with other teachers and a teacher educator in a community of practice (Wenger, 1998). In this way, the MAM program is modelling a form of PD which can be used as an aid or a thinking tool that contributes to create developmental structures adjusted to the school. As such, the MAM program can become a mediating artifact (Engeström, 1987), not only for improving mathematics teachers' classroom practices towards ambitious teaching (Lampert et al., 2010), but also for building a foundation for mathematics teachers' PD in general. To take advantage of this opportunity, the principal has to take part in the program so he can learn and manage to lead the development processes after the program period is over, as it is the school leaders' task to arrange and facilitate the teachers' learning in schools (Elmore, 2000).

Supporting the School Leader

The study presented in this article has shown that leading mathematics teachers' PD is easier said than done. With an explicit focus on teachers' PD and the knowledge that it has to be managed, led, encouraged, and supported (Earley & Bubb, 2004; Elmore, 2000; King & Stevenson, 2017; Silva et al., 2017), one might quickly forget that the need for support also refers to the school leader. As the overall leader supplying the school with development resources, and as the initiator of the MAM program, the school owner has to be placed in the community of the activity system as well (Engeström, 1987, 1999, 2001). The school owner's role must therefore be to support the school leader in conducting development work at school by providing resources, for example, internal or external support, that enable the school leader to conduct his work in the best possible way. However, such goal-directed actions were not clear in this study. The school leader's uncertainty relating to who is in control and who is making the decisions strongly indicates a need for more clearly defined roles. The latter, in combination with a top-down initiated development program, rather indicates that the school owner is stepping away from liability. The conducted work or goal-directed actions have not been divided between the people in the shared community and this leads to a tension in the division of labour (Engeström, 1987).

Hulsbos et al. (2016) found that reflecting with colleagues and participating in networks are workspace learning activities that are highly appreciated by leaders. As several schools are participating in the MAM program, the program itself could serve as a starting point for creating a network for the leaders from the participating schools. The school leaders could in this way draw on each other's experiences, thus developing their own profession as school leaders. However, as Earley and Bubb (2004, p. 80) found, "professional development does not just happen—it has to be managed and led". While it may not be the school owners' responsibility to lead these kinds of networks, it is the school owners' responsibility, as the overriding leader, to support and enable these networks to blossom, which could be done by supplying external expertise. In the same way as the school leaders need to acknowledge their role as facilitators for teachers' learning (Walker, 2007), this study has shown that the school owners also need to acknowledge their role as facilitators for the school leaders' work as leaders of teachers' PD.

CONCLUSION

In exploring how school management facilitates and supports mathematics teachers' PD when they participate in a practice-based development program, this study has found that words do not necessarily become deed, or practice, on their own. The school needs to have a structure and a practice for development work if a development plan is to be successfully implemented and conducted. Furthermore, the study presented in this article has illuminated how difficult development work can be if those involved do not aim their actions in the same direction. Teacher ownership and a shared overarching goal must be the foundation and form the basis for participating in a practice-based development program. By using the activity system as the unit of analysis, I have identified tensions and contradictions relating to the mathematics teachers' development work that can be the point of departure for change and development. The MAM program was supposed to be an aid or a tool that could help the mathematics teachers to develop their classroom practice and can thus be considered to be a mediating artifact. The findings indicate that the roles involved in the development work were not defined so that the conducted work or goal-directed actions divided between the people in the shared community act towards

the same object. Furthermore, the school leader needs support in his work as a leader of teachers' PD, and the school owner must acknowledge his role as the facilitator for this work.

Further research should aim to understand how school management should be included in such practice-based development programs for teachers. As such, school management can also develop their professionalism and be better prepared to facilitate and support the teachers' development work during the program and after its completion. The development program can then serve as a mediating artifact for mathematics teachers' PD.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

EAB conducted the research, analyzed the data and is the author of this manuscript.

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