Initiating a conceptualization of the professional work of teaching mathematics in kindergarten in terms of discourse

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This study investigates a Norwegian kindergarten teacher's work of teaching mathematics in an everyday activity involving play with Lego™ bricks. Analysis of the kindergarten teacher's discourse identifies questioning and affirmation as two core components. We suggest that these are core discursive practices in the work of teaching mathematics in kindergarten. In identifying these practices, a theory of thinking as communicating is applied to investigate what makes these discursive acts of teaching mathematical. Further research is called for to continue investigating kindergarten teachers' discursive practices in teaching and to continue the efforts to conceptualize the work of teaching mathematics in kindergarten in terms of discourse.

This article focuses on the work of teaching mathematics in kindergarten. Whereas the work of teaching in general refers to everything a teacher does in order to facilitate children's learning (Ball & Forzani, 2009), we focus in particular on kindergarten teachers' communication of mathematics – referred to as a discourse of teaching – and the practices that constitute this discourse. Although a kindergarten teacher participates in diverse discourses of teaching, we are mainly interested in the discourse of teaching mathematics. Our concept of mathematical discourse of teaching parallels what Adler and Ronda (2014) refer to as "mathematics discourse in instruction". The purpose of this article is to investigate the mathematical discourse of teaching in a Norwegian kindergarten context and we thereby aim at contributing to a larger effort to conceptualize the work of teaching mathematics in kindergarten.

Our study is situated within a sociocultural perspective where communication is seen as the main tool that mediates learning (Vygotsky, 1986). From this perspective, language not only mediates thinking and

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learning, but language constitutes reality (Säljö, 2001). In particular, we apply perspectives from Sfard's (2008) theory of thinking as communicating in our investigation of a kindergarten teacher's mathematical discourse in teaching. We approach the following research question:

> What are the core components of a kindergarten teacher's discourse of teaching mathematics and to what extent is this discourse *mathematical*?

Embedded in our attempt to respond to this research question is a desire to initiate a conceptualization of the work of teaching mathematics in kindergarten in terms of discourse by applying Sfard's (2008) theory. Before entering into this theoretical perspective, however, we briefly present some relevant literature on the work of teaching mathematics in school and kindergarten contexts.

Literature review

Although researchers have investigated various aspects of children's learning of mathematics – and numerous theories concerning children's mathematical learning exist – teaching of early mathematics has received much less attention. In the aftermath of Lortie's (1975) call for developing a language to describe the work of teaching, attempts have been made to conceptualize the work of teaching mathematics in school. An example is the conceptual-analytical work of Deborah Ball and her colleagues at the University of Michigan (e.g. Ball & Forzani, 2009; Ball, Thames & Phelps, 2008). With a focus on the mathematical work that teachers do in connection with mathematics teaching, these researchers assume that mathematics teaching is a professional practice (Ball & Forzani, 2009; Hoover, Mosvold & Fauskanger, 2014). In their job analysis of the professional work of teaching mathematics, they have identified some core components of the work of teaching, and they refer to these components as tasks of teaching (e.g. Ball & Bass, 2003; Ball & Forzani, 2009; Ball, Thames & Phelps, 2008). To emphasize that these tasks are mathematical – and that they are specific to the work of teaching mathematics – they sometimes refer to them as mathematical tasks of teaching mathematics (Hoover et al., 2014).

When other researchers draw upon the work of Ball and colleagues, they often focus on the categorization of mathematics teachers' knowledge into subject matter knowledge and pedagogical content knowledge – and sub-categories. Some important foundational aspects often seem to be overlooked, however, and Hoover and colleagues (2014, p. 11) emphasize "1) the role of the discipline of mathematics in and for teaching; 2) the

meaning of the term 'teaching' in the phrase 'for teaching'; and 3) the mutual importance of both conceptual work and the validation of proposed conceptualizations in advancing early-stage research". These perspectives also inform our study, but we approach them from a different theoretical stance.

While the research by Ball and colleagues can be described as cognitively laden, other researchers have attempted to investigate the work of teaching mathematics from a discursive perspective (e.g. Adler & Ronda, 2014; Venkat & Adler, 2012). Some of these studies draw upon Sfard's (2008) theory of thinking as communicating and, in that sense, our approach is related to the efforts by Adler and colleagues. Their framework is developed from analyses of mathematics teaching in South Africa. When they discuss "mathematical discourse in instruction", they refer to the mathematical components of everything teachers say, write and do in the mathematics classroom (Venkat & Adler, 2012). In the framework of Adler and Ronda (2014), two acts of discourse were particularly emphasized: exemplification and explanation. They suggest that presenting relevant examples and explaining these examples, as well as the mathematics involved in them, constitute a major element of mathematics teachers' work. In our study, we follow Adler and Ronda as we focus on discursive practices or acts of discourse as core components of the work of teaching mathematics in kindergarten. Although the South African school context is different from the Norwegian kindergarten context, we still find the framework of Adler and Ronda useful in our efforts to conceptualize the work of teaching mathematics in kindergarten.

Numerous studies have investigated the work of teaching mathematics in school, but fewer efforts have been made to conceptualize the work of teaching mathematics in a kindergarten context. One example is a study by Carlsen, Erfjord and Hundeland (2010). When investigating one Norwegian kindergarten teacher's practice, they found that this kindergarten teacher used questioning in different ways in order to help the children reflect mathematically. The Norwegian kindergarten context is often referred as a sociocultural tradition, as compared to a "pre-primary" tradition in the U.S. and other countries (OECD, 2006). In the Nordic countries, kindergarten teachers tend to avoid using the word "teaching" to describe their professional work (e.g. Hedefalk, Almqvist & Lundqvist, 2015) – a similar evasion can be observed in official documents – and endeavoring into a conceptualization of the work of teaching mathematics in such a kindergarten context thus seems particularly pertinent. Since everyday activities and free play is more common than classroom lessons in the Norwegian kindergarten tradition, we have focused on an everyday situation in this study. When analyzing the kindergarten

teacher's discourse in order to investigate core components of this discourse, and discuss how this discourse is mathematical, we apply Sfard's (2008) theory of commognition.

Theoretical background

Sfard's (2008) theory of thinking as communicating is a complex theory of learning and we only apply certain aspects of this theory in the present article. Throughout her theory, Sfard attempts to define and use concepts related to learning in terms of observable discourse. This is related to a core idea of how cognition and communication are inextricably connected. To emphasize this, she introduce the new term "commognition".

When trying to understand everything in terms of communication and discourse, it is necessary to be specific about how you understand these concepts. Sfard defines communication as "a collectively performed patterned activity" (Sfard, 2008, p. 86). When people talk to each other, their talk can be described as a patterned activity – and thus as communication. Sfard's concept of communication is not, however, limited to verbal talk only, but it also includes non-verbal communication like gestures and body language. From this definition of communication, a discourse refers to a certain type of communication that includes some people and excludes someone else. A discourse of teaching mathematics in kindergarten is thus a particular type of communication that is specific to the work that kindergarten teachers perform.

In order for a discourse to be regarded as mathematical, Sfard (2008) suggests the following criteria: 1) word use, 2) visual mediators, 3) endorsed narratives, and 4) routines. A mathematical discourse is charac-terized by its use of particular mathematical words and these words are used in a "mathematical" way. Oftentimes, a mathematical discourse also includes certain visual mediators. These visual mediators include symbols or artefacts like numerals, mathematical operators and signs. The objects of a mathematical discourse are described in narratives that can be endorsed or rejected and the production of new endorsable narratives can be described as the goal of a mathematical discourse. For instance, axioms and definitions are proposed and these are used in particular ways in order to construct theorems that the participants in the mathematical discourse aim at proving. The actions performed by the participants in a mathematical discourse typically follow certain patterns and Sfard (2008) refers to these patterns as routines. Explorations is one kind of mathematical routines, whereas rituals and deeds are other kinds of mathematical routines. Deeds – referring to practical actions that lead to change in objects – are commonly used mathematical routines in the discourse of smaller children.

In all theories of learning, learning is defined as a change of something and Sfard (2008) defines learning as change of discourse. This change of discourse can either be on an object-level or meta-level. An object-level change could be the introduction of a new word in a discourse. For example, children could start talking about circles instead of round figures or shapes. A meta-level change, on the other hand, includes a change in the rules that govern the discourse. One example could be that the participants in a discourse start using a word in a new way, but it could also be that the routines in the discourse change.

When we investigate the discourse of teaching in this study, we follow Sfard's theory, and we focus in particular on components of this discourse. The core components of this discourse of teaching are referred to as discursive practices, acts of communication or acts of discourse. From the inclusive definition of communication, this might include any verbal or bodily act that aims at communicating something. For sake of simplicity, however, we focus mainly on the verbal practices or acts of communication in this article.

The study

In order to investigate core aspects of kindergarten teachers' mathematical discourse for teaching, we designed a case-study (Stake, 1995). The phenomenon we wanted to study was the work of teaching mathematics in kindergarten. In the Norwegian kindergarten context, mathematics is normally "taught" through everyday activities and play situations, so we asked a kindergarten teacher for permission to video record an everyday activity with his group of children in the kindergarten. We wanted to observe an experienced kindergarten teacher, because we anticipated that an experienced kindergarten teacher might provide more extensive reflections about his work of teaching than someone with less experience. This teacher had 17 years of experience and he had finished his education before mathematics was introduced as a course in the Norwegian kindergarten teacher education. This particular kindergarten had six departments. In this department, there was one kindergarten teacher and two assistants together with 18 children aged 3–6 years old. The teacher decided to set up an activity with six children that involved playing with Lego™ bricks. In this situation, the teacher and the children interacted while seated around a table, played with the bricks and talked about what they were doing. The youngest was 3,11 years old (3 years and 11 months) and the oldest child was 5,4 years old. The kindergarten teacher decided to initiate a situation that involved playing with Lego, since he believed that such an activity might include mathematics. In the Norwegian kindergarten context, there is a strong focus on play and

learning in informal everyday activities. The kindergarten teacher thus organized this situation without any formal goals and without telling the children that this was about mathematics. This play situation lasted for 22 minutes.

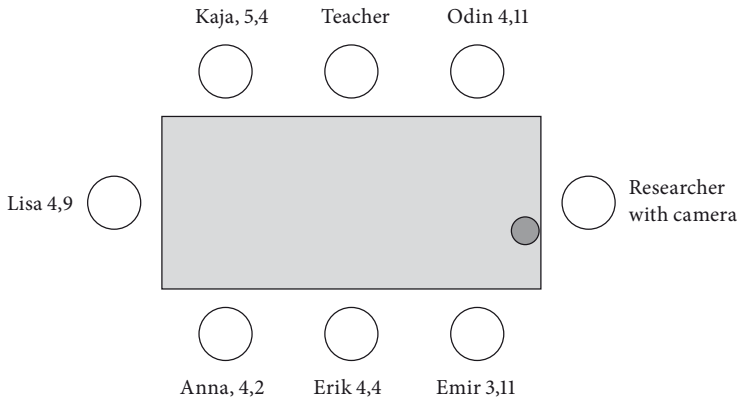

Figure 1. *Seating of the participants around the table*

Since we aimed at investigating a representative case, we asked the kindergarten teacher to set up an activity that he believed involved doing mathematics. He was told that it should be an everyday activity – a kind of activity that he would normally organize with the children. He decided to use a playgroup with six children and he explained that this is something they do twice a week in this kindergarten. The first author of this article video recorded the activity as a passive observer. Although he was only with the children in this particular activity, the children appeared focused on the activity and did not seem to be distracted by his presence. They had been informed in advance that a person would come and video record their play with Lego bricks.

After the observation, a DVD with the recording of the activity was given to the kindergarten teacher. An interview was carried out three weeks after the observation. The DVD was used as stimulated recall in the interview and the kindergarten teacher commented on what he saw in the video. The first author transcribed the observed activity as well as the recordings from the interview verbatim.

The analysis of data in this study was carried out in two phases. In the first phase, conventional content analysis was applied to analyze the transcripts from the Lego situation (see Fauskanger & Mosvold, 2015). The unit of analysis was the play situation as it had been transcribed and the analysis started with a careful reading of the content of the transcripts.

Codes and categories were developed inductively through the analysis process, without any existing categories from earlier research. This way of approaching the data material is common when the aim is to describe a phenomenon and we thus decided that it was useful for investigating the kindergarten teacher's discourse of teaching. This approach also has similarities with grounded theory and constant comparative method (Berg & Lune, 2012; Corbin & Strauss, 2015). The open coding resulted in two core categories: questioning and affirmation. In the final stage of this first analysis phase, the occurrences of codes and categories were counted.

In the second phase of data analysis, Sfard's (2008) commognitive theory was used in a theory-driven analysis of the data. Our focus was on analyzing characteristics of the kindergarten teacher's discourse rather than children's learning and we used the theoretical perspectives from Sfard's theory that focus on characteristics of a mathematical discourse.

From the process of open coding, the following list of codes were developed:

MQ: mathematical question

MA: mathematical affirmation

MO: other talk (mathematical, e.g. telling or presenting)

GQ: general question

GA: general affirmation

O: other talk (general talk, including seeking joint attention)

Every utterance of the kindergarten teacher was coded with this set of codes. We counted the number of occurrences of each question, affirmation and other speech acts – following the coding list above – to enable a more rigorous description of the kindergarten teacher's discourse. Some questions did not include mathematical word use or visual mediators, but they could still be coded as mathematical if the context indicated that the question was part of a mathematical routine or endorsed narrative. The kindergarten teacher would also, in some instances, make the question or affirmation mathematical by physical acts or gestures in which visual mediators were used in a way that indicated a mathematical discourse (Sfard, 2008). One example is when the kindergarten teacher was building a tower of Lego bricks and then he posed the question: "What if I do like this?" He immediately followed up by posing another question: "Will it make a difference then?" There are no distinctly mathematical words in these questions, but he makes use of visual mediators (the Lego

bricks) in order to pose questions that call for a mathematical exploration – which can be referred to as a mathematical routine. Because of this, we code the question(s) as mathematical.

The video recordings and the interview were carried out in May, 2014 and the project was subject to notification and approved by the *Norwegian social science data services*. The owner of the kindergarten where we did the recordings, the kindergarten teacher and the parents of the six children gave written consent. Throughout the analysis, the names of the children, the kindergarten teacher as well as the kindergarten were replaced by pseudonyms.

Findings

Our research question first aimed at identifying core components of the kindergarten teacher's discourse and second it aimed at discussing to what extent the kindergarten teacher's discourse of teaching was mathematical. We attempt to answer the first part of our research question by presenting and discussing results from the inductive analyses of the verbal discourse, as it was documented in the transcripts from the Lego building situation. In order to answer the second part of the research question, we apply aspects from Sfard's (2008) theory of commognition in a more in-depth analysis and discussion of a selected episode from the same situation. In this part, we also draw upon data from the teacher interview.

Describing the kindergarten teacher's discourse

Initial analyses of the kindergarten teacher's discourse indicated that the act of asking questions was prevalent and most of his utterances, it seemed, could either be categorized as asking questions or affirming the children's responses. This corresponds well with the classic IRE (initiation-response-evaluation) pattern and the kindergarten teacher's emphasis on questioning also corresponds well with what other researchers have found in studies of children's mathematical reflections in conversations with kindergarten teachers in the Norwegian kindergarten context (Carlsen, 2013; Carlsen, Erfjord & Hundeland, 2010). The questions served as an initiation and, depending on the children's response, the kindergarten teacher would often follow up either by affirming the response or by asking another question. We found it interesting to observe that the kindergarten teacher's discourse appeared to have a strong focus on the acts of questioning and affirmation. Further analysis of the data material supported this initial indication and questioning and affirmation

emerged as the two most prominent discursive acts carried out by the kindergarten teacher in this situation. Both questions and affirmation might initiate mathematical thinking, but it seems like the purposes of questions vary; some initiate use of mathematical words, some initiate mathematical argumentation and some invite the children to participate in the mathematical discourse (Sfard refers to this as "mathematizing"). The affirmations also seem to have different purposes; the teacher uses them to introduce new concepts/words, to stimulate further thinking, to confirm or to appraise children's utterances. The teacher does not use correction of error in his work. Instead he re-phrases the question to make the concepts mathematically correct. He indicates that a focus on reaching joint attention about the mathematical object of the discourse is important for him in his work.

Table 1. *The kindergarten teacher's discursive acts in the Lego activity*

Code	Number of discursive acts	Relative frequency
Non-mathematical	77	0,36
General questioning	37	0,17
General affirmation	22	0,10
Other talk	18	0,08
Mathematical	135	0,64
Mathematical questioning	82	0,39
Mathematical affirmation	44	0,21
Other talk (mathematical)	9	0,04
Sum	212	1,00

When we coded every utterance of the kindergarten teacher deductively, by using the codes that were developed in the inductive phase, we found that almost half of the discursive acts made by the kindergarten teacher throughout the situation were in the form of a question. Altogether 31 % of the discursive acts were coded as affirmations.

When distinguishing further between these acts of discourse, we found that 39 % of the kindergarten teacher's discursive acts appeared to be mathematical questions, whereas 21 % were coded as mathematical affirmation. More than half of the kindergarten teacher's communication throughout this situation was coded as mathematical discourse. Given that the kindergarten teacher was asked to organize a situation that involved mathematics, such a large amount of mathematical communication is not surprising. We were surprised, however, by the large number

of questions asked. In our continued analysis, we found different combinations of questions and/or affirmations. A mathematical question might follow a general question, or it might be followed by another mathematical question if the children do not respond; a mathematical question might also follow another mathematical question to increase precision and/or avoid misunderstandings. No particular patterns were found in the sequencing of the different types of questions and the same lack of clear patterns emerged for affirmations. It did, however, appear that these questions and affirmations were used to focus the children's attention on the mathematical objects. The use of questions and affirmations also appeared to instigate a move towards explorations in the discourse.

In the next section, we examine a selected episode from this situation more in-depth and we use some aspects from Sfard's (2008) theory as an analytic framework in order to discuss if and how the discourse can be described as mathematical.

Digging deeper into the kindergarten teacher's mathematical discourse

We use the following episode as an example of the kindergarten teacher's discourse in the Lego situation. We include the entire sequence of the exchanges – including the voices of the children – in order to provide a more situated perspective of the kindergarten teacher's speech acts as they occurred in the context. We also include comments by the kindergarten teacher as voiceover. These comments were made by the kindergarten teacher while watching the video in the interview and these comments provided useful information about the purpose of the kindergarten teacher's discursive acts.

128 T: [shows a red rectangle-shaped brick] But now I want a red one. Can you find, I don't want a rectangle [switches to a red brick with shape of a square]. I want five red squares.

129 T: Was it seventeen? Yes, that might be correct.

[Voiceover/teacher: *She got one more than Odin. He was the one who had counted them. I had not counted myself and I didn't know how many there were. I kind of took his word for it.*]

130 T: Five red quadratic shapes.

131 Odin: No, not five. We need more than that.

132 T: Do you want even more than that? But first I want five.

133 Erik: I found!

134 T: How many are there then?

135 Erik: Two.

136 T: [holds up the brick] Are there two?

137 Erik: No, but you got one there and then one there [points at the other one].

[Voiceover/teacher: *They are very focused on quantity and it appears very easy; they immediately get it.*]

138 T: Yes, that is correct. Altogether, there are two.

139 Odin: [adds a brick to the tower he is building] And one more. And two more. Five, now you have five already!

140 T: Five? Are you sure about that? [Holds up the tower]

141 Odin: Yes. [starts counting out loud while he is pointing] One-two-three-four-five [small pause] six. Six, you got one extra.

[Voiceover/teacher: *This was good. You got one extra, he said. It was the sixth one that was extra. He didn't count, but he only subtracted one then. Because that is the thing about counting, that you are able to visualize things without physically having to count them.*]

142 T: Very good. [puts down the bricks] But then I can, this will actually be a pillar, can you see that?

The episode starts with the teacher holding up a red Lego brick, shaped as a rectangle (128). He uses this brick as a visual mediator for posing a mathematical question that is formulated as a request. "I don't want a rectangle", he says, and he then picks up another brick with the shape of a square, but "I want five red squares". The words "rectangle" and "square" are mathematical terms and they have a particular and precise definition in mathematics. The kindergarten teacher does not deal with the definition here, but he rather uses these particular bricks as visual mediators to indicate the difference between rectangles and squares. Then, in the middle of this question, where he requests a particular number of bricks – five red squares – he redirects his attention to another child, who has counted her bricks. This utterance (129) provides an example of a mathematical question that is followed up by an affirmation. In and of itself, the affirmation – "Yes, that might be correct" – does not include any mathematical words. From the context, however, and from the kindergarten teacher's voiceover from the interview, we conclude that it is mathematical in that it serves as an endorsed narrative in this discourse about quantity.

Following this, the kindergarten teacher immediately redirects his attention back to his request of five red quadratic bricks (130). This mathematical affirmation is followed up by Odin's statement that they need more than five (131). The kindergarten teacher's response to that contains the word "more" and he then affirms that he wants a certain quantity (five), but this question (132) still appears as a more general question because it seems to relate more to his wish than any mathematical considerations.

When Erik finds another red brick (133), the kindergarten teacher poses a mathematical question: "How many are there then?" This question involves a prompt ("how many?") that intends to initiate a certain routine. A typical routine for responding to a question about quantity in this mathematical discourse is to count, but Erik does not respond by counting. Instead, he immediately sees that there are only two bricks (135). This is an indication of subitizing – the ability to recognize small quantities without counting. The kindergarten teacher responds by asking a mathematical question that motivates Erik to back up his response by a mathematical argument – there was one brick and then he got one more (136–137). In the voiceover, the kindergarten teacher comments that the children focus on quantity and that they immediately recognize these small quantities. He follows up on Erik's response by affirming that there are two bricks.

At the same time, Odin puts another brick on top of the tower he is building. He comments that when adding this one and then two more, there are already five bricks in the tower (139). The kindergarten teacher's response is to pose a mathematical question: "Are you sure about that?" (140) This question calls for a substantiation, which is an exploratory routine in which the participant of the mathematical discourse must decide whether or not to endorse the constructed narrative (Sfard, 2008). Odin follows up by affirming and he starts counting to prove. When he gets to five, he pauses slightly before commenting that there are six, because he got an extra brick. In the voiceover, the kindergarten teacher comments that Odin had observed that there were five bricks and that the sixth one was an extra brick. Following up on Odin's utterance, the kindergarten teacher affirms, before he redirects the attention from the quantity of bricks to the shape of the tower that is constituted by the bricks. This utterance (142) serves as a prompt to switch focus from one mathematical aspect of the visual mediators to another.

Concluding discussion

Based on the findings from this study, we suggest that questioning and affirmation are two core discursive practices in the work of teaching mathematics in kindergarten. Carlsen and colleagues (2010) also emphasized the role of questioning in their study of a Norwegian kindergarten teacher. The findings from our study support their claim about the prevalence of questioning in the work of teaching mathematics in kindergarten, but our study expands these previous findings by suggesting that questioning and affirmation serve as two important – and strongly connected – discursive practices. These findings indicate that

the core discursive practices of kindergarten teachers differ from the practices of mathematics teachers in school. In their study of mathematics teaching in South Africa, Adler and Ronda (2014) emphasized exemplification and explanation as two core components in the teachers' mathematical discourse of teaching. Rowland (2008) also emphasized presentation of examples as particularly important for mathematics teachers. We suggest that questioning and affirmation might be more prevalent discursive practices in a kindergarten context – at least in a Nordic kindergarten tradition.

In our study, we not only identify questioning and affirmation as core practices. Using Sfard's (2008) theory of thinking as communicating as an analytical framework has helped us investigate the extent to which these discursive practices are mathematical or not and what role they play in the mathematical discourse. We have focused on discussing the following four core aspects that make a discourse mathematical: 1) word use, 2) visual mediators, 3) endorsed narratives, and 4) routines. Through his use of questions and affirmations, the kindergarten teacher sought to turn children's attention from the act of playing with Lego bricks to describing this activity with mathematical words. The kindergarten teacher introduced mathematical words through questions and affirmations and thus facilitated children's learning on object-level as well as meta-level. Introduction of new words in a discourse leads to object-level learning, whereas questions that initiate thinking about how mathematical words are used and what they mean might lead to meta-level learning (Sfard, 2008). Through his questions and affirmations, the kindergarten teacher turned the Lego play activity into a mathematical discourse and the Lego bricks were used as visual mediators in this discourse. Finally, his use of questions and affirmations triggered the children to move from a routine of deeds – focusing on practical manipulation of the Lego bricks – to a routine of exploration where the focus is on trying to make mathematical arguments about certain mathematical objects.

Our study has some limitations, of course, and we will briefly discuss some of the most important ones here. On the one hand, we have studied one situation in the work of one kindergarten teacher, only, and we therefore need to be careful about making generalizations. On the other hand, our in-depth analyses of this situation provide details about the work of teaching mathematics in kindergarten that might be useful for further research. The hypothesis about questioning and affirmation as core discursive practices in the work of teaching mathematics would be interesting to investigate further in other case-studies of Norwegian kindergarten teachers. Such studies would provide further insight into whether or not these are core aspects of the work of teaching

mathematics in Norwegian kindergartens. Similar studies, or possibly more large-scale and quantitative comparative studies, could be useful for investigating possible cultural differences in the work of teaching mathematics in different kindergarten contexts. We suggest that further conceptual-analytical work of this kind, along with more comparative studies – like we have suggested above – are crucial in the ongoing attempts to conceptualize the work of teaching mathematics in kindergarten. Such conceptualizations could potentially influence and enhance kindergarten teacher education and eventually lead to increased quality and professionalization of the work of teaching in kindergarten.

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