The work of leading mathematical discussions in kindergarten: a Norwegian case study

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The core practice of leading mathematical discussions has received considerable attention in the school context, but few studies have investigated this practice in a kindergarten context. This study investigates what tasks teachers might be faced with in the work of leading mathematical discussions in a Norwegian kindergarten context. Inductive analyses from a case study of a kindergarten teacher's discussion with a group of four children identify four tasks of teaching in the work of leading mathematical discussions: 1) use of concrete materials to facilitate mathematical play and investigations, 2) use of metaphors to describe mathematical concepts, 3) use of questions to elicit children's mathematical thinking, and 4) use of praise to support children's mathematical self-confidence.

Keywords: Mathematical discussions, kindergarten, tasks of teaching.

Introduction

Leading discussions is considered a core practice of mathematics teaching and there is a growing body of research on leading mathematical discussions (Jacobs & Spangler, 2017). This research builds on a longstanding interest in communication in mathematics education research. Whereas traditional teaching often follows a pattern of teacher initiation, student response and teacher evaluation (IRE), progressive teaching tends to focus more on discussion (Cazden, 2001). Much has been written about what is involved in teachers' work on structuring and leading mathematical discussions in school (e.g. Kazemi & Hintz, 2014), but much less focus has been placed on what is entailed in carrying out this core practice in the kindergarten context.

The Nordic kindergarten tradition emphasises care and upbringing through free play and everyday activities over school preparation. A few studies have provided insight into the communicative work of teaching mathematics in this context. For instance, Fosse (2016) identified five characteristics of mathematical conversation in a Norwegian kindergarten. Whereas she focused more on conversations among children, Carlsen (2013) targeted the orchestrating work of a Norwegian kindergarten teacher's use of fairy tales. He concluded that concrete materials and questioning were important tools that mediated the discussion. Sæbbe and Mosvold (2016) also found that the use of questions was important in their study of teaching mathematics through play with Lego blocks. They added affirmation as a core aspect in a teaching situation that seemed to be more in line with an IRE pattern than discussion. In a more recent study, Sæbbe and Mosvold (2020) discussed how initiation of mathematical discussions, responding to unexpected questions, dealing with wrong answers, using visual representations and positioning children as valuable contributors were core tasks in the complex work of teaching mathematics in kindergarten. Although communication and discussions were prominent in all of these studies of mathematics teaching in the Norwegian kindergarten context,

none of them had an explicit focus on the practice of leading mathematical discussions. Building on previous research on the core practice of leading mathematical discussions in school, and on previous research on mathematics teaching in the Norwegian kindergarten context, the present study aims to elaborate on the work of leading mathematical discussions in kindergarten. We approach this through the following research question:

> Which tasks of teaching are teachers faced with in the work of leading mathematical discussions in a Norwegian kindergarten context?

We will first provide some theoretical background and define some core terms that have been used in the study before presenting the design and our findings.

Theoretical background

We define discussion to be a specific kind of communication around a particular content that is distinct from other types of talk. Discussions are oriented towards a particular question or problem that a group investigates to build collective knowledge and understanding by using ideas and input from participants as resources. Whereas the traditional IRE pattern describes exchange between a teacher and individual children, more participants contribute in a discussion by making their ideas public, through active and careful listening or by responding to the contributions of other participants (Jacobs & Spangler, 2017). Mathematical discussions are not only discussions about mathematics, but also support a learning culture where children participate equitably on the joint construction of knowledge.

Focusing on discussion fits well with the Norwegian Framework Plan for Kindergartens, which reflects the social pedagogy tradition and emphasises a child-oriented pedagogy where care, play and development are core foci. The Framework Plan describes promotion of language and communication as a core duty of Norwegian kindergartens, and it specifies that this should be accomplished through dialogue and interaction (Directorate for Education and Training, 2017). Furthermore, the Framework Plan states that kindergartens shall help to create a learning community that values different expressions and opinions. The learning area of "Quantities, spaces and shapes" highlights asking questions, reasoning, argumentation and seeking solutions. It specifies that "staff shall use mathematical terminology thoughtfully and actively" and that "staff shall create opportunities for mathematical experiences by enriching the children's play and day-to-day lives with mathematical ideas and in-depth conversations" (p. 54). The Framework Plan states that kindergarten teachers must work deliberately in monitoring, facilitating and supporting dialogue with and between children. But what does this work of leading mathematical discussion entail? And what do we mean when we refer to it as a "work of teaching"?

Studies of leading mathematical discussions often distinguish between the actions or moves that teachers make when they orchestrate a discussion, and the intentions or goals that point to the intended outcome of the moves (Jacobs & Spangler, 2017). Although such a distinction appears logical, it is often challenging to distinguish the two in practice. For instance, "pressing students for explanations is both a set of moves and a set of goals, each with multiple layers" (p. 779). We use a different approach, where moves and goals are integrated in tasks of teaching (e.g. Ball, 2017; Sæbbe & Mosvold, 2020). An example of a task of teaching is "asking productive mathematical questions", illustrating how moves and goals are integrated in the tasks. Focusing on mathematical tasks of

teaching thus involves an effort to deconstruct the complex work of teaching into problems or challenges that teachers recurrently face in the complex work of teaching (Ball, 2017).

Methods

To investigate tasks of teaching that might be involved in the work of leading mathematical discussions in the Norwegian kindergarten context, we conducted a case study of one kindergarten teacher. Although a case study is bounded in time and place, it is considered useful for gaining an understanding on a particular issue (Creswell & Poth, 2018) – in our case, what might be involved in the work of leading a discussion on mathematics with young children in a kindergarten context. To recruit participants for the study, we used the network that was available through our work at Norwegian Centre for Mathematics Education, which involves various professional development efforts in kindergartens and schools. In particular, we searched among previous participants in recent professional development projects that focused on mathematical discussions in kindergarten. Two kindergarten teachers accepted the invitation to participate. One of them worked with toddlers, and due to the children's age and language development level we decided against selecting this teacher. Instead, we selected a kindergarten teacher who worked with children who were around four years old as we assumed that these children might be able to participate more fully in a discussion than toddlers. This kindergarten teacher – who had ten years of experience and continuing education in educational-psychological counselling – selected a group of four children to participate in the study. We asked the teacher to carry out an everyday activity or situation in which she felt that mathematical discussion was significant. She thus planned an open, play-based activity that allowed for mathematical investigation without specifying any particular mathematical theme. We received consent from the parents and children and informed all participants that they were free to withdraw from the study at any time.

The first author was responsible for data collection and had the role of a non-participant observer. Since our focus was on identifying tasks of teaching rather than on analysing details of communication, we decided to collect the data through fieldnotes from observations. The fieldnotes were written in three phases: during a conversation with the kindergarten teacher before the discussion, during the mathematical discussion between the kindergarten teacher and the four children gathered around a small table and in a semi-structured interview with the kindergarten teacher after the observation. To support the fieldnotes, we also photographed the room and materials used in the discussion. In the interview, we asked the kindergarten teacher to reflect on some experiences from the discussion. The purpose was to gain insight into reflections, challenges and purpose of choices. The fieldnotes were written in-situ and read through immediately after the observation so that the kindergarten teacher was available to respond to clarifying questions. Some notes were added when necessary.

Where other studies have identified moves and purposes that teachers might use when leading mathematical discussions (Jacobs & Spangler, 2017), our focus was on identifying possible tasks of teaching that might be involved in the work of leading mathematical discussions (e.g. Ball, 2017; Sæbbe & Mosvold, 2020). We thus focused on identifying possible tasks that kindergarten teachers might be challenged with during the work of leading discussions, rather than to describe and evaluate what a particular kindergarten teacher did. The analysis process was open and inductive, where two criteria guided our identification of tasks of teaching. First, in order for something to be identified as

a task of teaching, it had to be *recurrent*. For instance, we noticed several times throughout the activity that the kindergarten teacher used questions. Use of questions therefore seemed to be a recurrent task. Since our analysis was limited to one activity, we sometimes inferred that something was recurrent by observing that children seemed to be familiar with it. Second, tasks of teaching have to be *deliberate*. This was accounted for by a semi-structured stimulated recall interview with the kindergarten teacher directly after the observation. Through this process, four tasks of teaching emerged as prevalent in this activity, and these are presented and discussed below.

Findings

Use of concrete materials to facilitate mathematical play and investigations

We have identified using concrete materials to facilitate mathematical play and investigations as a task that might be involved in the work of leading mathematical discussions in kindergarten. Different types of concrete materials are frequently used in kindergarten. A broad distinction can be made between materials that are developed specifically for the learning of mathematics, and materials that were not developed for this specific purpose. In our study, we observed the kindergarten teacher using several types of concrete materials, including Numicon® shapes, pegs in a feely bag and baseboard, counting bears, pattern cards for bears and a balancing scale, and three towers of Lego Duplo® in different colours. Numicon® shapes and counting bears are educational resources developed specifically for learning mathematics, where provided guidelines and web resources elaborate on the intentions behind these materials. Other materials, such as Lego Duplo®, have not been developed for the purpose of learning mathematics, but they can still be used as artefacts to direct children's attention towards mathematics.

Bearing the findings from our analysis in mind, we suggest that there are at least two possible ways in which concrete materials can be used when leading mathematical discussions in kindergarten. First, the concrete materials might serve as a starting point for a mathematical discussion. In our study, we observed how the kindergarten teacher let the children play with concrete materials, and then used their play as a starting point for initiating a discussion by asking them questions related to the materials or what they did with the materials. In this sense, concrete materials might create a common focus. Second, our analysis indicates that the material played a significant role not only for initiating discussions, but also for orchestrating the mathematical discussion. For instance, the kindergarten teacher asked questions about the concrete materials rather than directly about the more abstract mathematical ideas in focus.

There are several reasons why a kindergarten teacher might consider using concrete materials in mathematical discussions. In the interview, the kindergarten teacher in our study explained that the children had been motivated to play with this material in the past. A possible purpose behind the choice of using concrete materials might thus be to increase children's motivation and interest. The kindergarten teacher in this case study decided to make materials with the potential for both play and mathematics learning available to the children with the intention of observing the children's play and interest as a starting point for mathematical discussions. We observe that there is a close connection between the questions of how and why concrete materials might be used here. The task of using concrete materials to initiate mathematical discussions thus involves both moves and purposes (Jacobs & Spangler, 2017).

Use of metaphors to describe mathematical concepts

Another task of teaching that we identified as part of the work of leading mathematical discussions in this kindergarten context is the use of metaphors to make mathematical ideas accessible to the children. Whereas the concrete materials discussed above are physical objects that might help direct children's attention towards mathematical ideas, a metaphor is a word or phrase that is used to describe something that is analogous to something else – for instance a mathematical idea.

In our study, we observed that the kindergarten teacher made frequent use of metaphors when leading the mathematical discussion. She used metaphors relating to colour, numbers, shapes, context and more. For instance, when referring to a brown shape, she said: "It looks like chocolate". When referring to a shape with a circle in it, she described it as "an eye". When describing a shape with an odd number of circles, one a protruding extension, she described it as a "diving board". She also extended the use of metaphors to provide a context for the mathematical issue in focus. An example of this was when they were discussing why they should place the counting bears in a particular way in order to continue the pattern. The kindergarten teacher described this to the children as: "the bear is coming to a birthday party".

When it comes to purpose, metaphors can be used to make ideas accessible to the children, but they can also create a low threshold so that more children can participate in the mathematical discussion. In our study, the kindergarten teacher used metaphors with the intention of supporting children's understanding of the ideas they discussed. After the activity, however, the kindergarten teacher reflected on a possible unintended effect of her use of metaphors. She was worried that her use of the birthday party metaphor might have contributed to obscuring the mathematical focus for one of the children. One child selected a bear with a similar colour so that the two bears could "be friends" in the party, rather than selecting a green bear that would continue the intended pattern on the task card. We therefore suggest that metaphors cannot always be used in a straightforward way, but using them constitutes a task of teaching where the kindergarten teacher has to consider and make a decision based on her professional knowledge and understanding of the context, the children and the mathematical content that is in focus in the discussion.

Use of questions to elicit children's mathematical thinking

A third task of teaching that we found to be involved in the work of leading mathematical discussions in kindergarten involved using questions to elicit children's mathematical thinking. Questions are common in the more traditional IRE pattern of teaching (Cazden, 2001), but the work of leading mathematical discussions might also involve questions. A discussion is initiated by a question or problem that the group aims at exploring in order to increase their knowledge, but questions might also be used when orchestrating a discussion. Below, we discuss two broad categories of questions that we observed in the orchestration phase and possible purposes or effects of such questions.

The first category of questions might be described as probing questions. These are often "closed", in that they only call for short answers. Examples of such questions that we observed in our study are: "Which piece is this?" and "What size is this piece?" It was interesting to note that the kindergarten teacher in our study was not able to recall examples of such questions in the interview, and we therefore suspect that these questions might have been posed habitually rather than purposefully. However, use of such questions tends to lead to recitation rather than discussion (Cazden, 2001), so

it is important to be aware of the potential effects of such questions. When asked directly about the purpose of such questions, the kindergarten teacher in our study assumed that they helped the children to maintain their attention on the mathematical issue or task in focus.

Another category of questions might be described as eliciting questions. These questions tend to be more "open", and are questions for which the teacher does not know the answer. An example of an eliciting question that we observed in our study was when the teacher asked in the group: "Why did you choose to put that one there?" This is a type of question that invites children to explain their thinking rather than to probe their understanding. When asked why she posed such questions, the teacher admitted that she actually was wondering why the child had done as she did. This indicates that eliciting questions might also be questions where the kindergarten teacher genuinely wonders about the answer herself. Another purpose of asking eliciting questions might be to make children's thinking more publicly available to other participants in the discussion. Examples of such questions that we observed asked in the group are: "How do you know?" and "Can you show me?" The questions support children in explaining and showing their ideas on the table so that the other children can engage in them. Another example of this type of question was when the kindergarten teacher asked one of the children: "Why did you want to have a red one there?" This use of questions is often described as pressing for clarification and reasoning, and researchers have identified specific talk moves that are types of questions that can be used in the work of leading mathematical discussions to elicit children's thinking (e.g. Kazemi & Hintz, 2014). Considering the different purposes of the questions posed, we get a notion of the complexity that is involved in the task of choosing and using different types of questions in mathematical discussions.

Use of praise to support children's mathematical self-confidence

A fourth task of teaching that we identified in our analysis relates to the use of praise. Praise is given frequently in the more traditional IRE pattern as feedback or evaluation (e.g. Cazden, 2001), but our analysis shows that it might also be involved in the work of leading discussions. We identified two types of praise in the analysis of our data.

The first type of praise is when the teacher aims at orienting the children towards other children's thinking, and towards understanding that there are many ways of thinking. An example is when the kindergarten teacher in our study said: "Yes, that can be the right solution for you!" The teacher highlights that for the purpose of this move to work as intended, it has to be stated in front of the group, which indicates that the teacher was deliberate about this.

Second, praise might be used in discussions to encourage children or make them feel good about themselves. An example of this is a situation when a child identified a shape with ten holes, and the kindergarten teacher provided the following praise: "You can really count far!" As a result, the children shifted focus and started counting as far and fast as they could. This illustrates how use of praise might have unintended consequences. A kindergarten teacher might consider it important to make sure that children feel smart, and there might be reasons why mathematics is a topic where this type of praise is considered especially important. The kindergarten teacher in our study expressed concern about the tendency of children to be vulnerable to negative feelings about mathematics, and she argued that at this age, building positive attitudes towards mathematics is more important than

doing tasks correctly. It is worth noting, however, that this use of praise is similar to the use of feedback in traditional recitation.

Our analysis indicates that the use of praise can be challenging – particularly in unexpected situations. One example is when a child in our study presented a solution to the pattern task that appeared to be mathematically incorrect. The other children in the group sensed this and made some negative comments. In this situation, the teacher overlooked the comments. In the interview afterwards, the teacher admitted that she had been uncertain about how to respond in this situation, and she decided to deal with it later. Her concern was to avoid making the situation worse, and her plan was to take the necessary actions with the aim of raising the child's status in the group later the same day. This example shows how challenging it can be to respond to children's contributions in the moment. Many discussions start out with children being asked to explain their thinking, and some teachers tend to treat all contributions as equally good. How to follow up on an idea and deciding when and how to use praise to support children's mathematical self-confidence is thus a complex task of teaching that is involved in the work of leading mathematical discussions in kindergarten.

Concluding discussion

We set out to examine which tasks of teaching are involved in leading mathematical discussions in the Norwegian kindergarten context. Our case study of one kindergarten teacher's practice cannot be generalised to a larger population, but we consider this case study as a proxy for studying what might be involved in the work of leading mathematical discussions in the kindergarten context. Through our analysis, we have identified four tasks of teaching that involve choosing and using appropriate concrete materials, metaphors, questions and praise. We suggest that these tasks of teaching illustrate some of the complexity that is involved in the work of leading mathematical discussions.

Several previous studies have identified questioning as important in the work of teaching mathematics, also in the Norwegian kindergarten context (e.g. Carlsen, 2013; Fosse, 2016; Sæbbe & Mosvold, 2016). In the context of discussion, the use of questions to elicit children's thinking appears particularly important. This corresponds with Fosse's (2016) emphasis on the need for reflection. Our identification of the use of praise appears to correspond with other studies that have pointed out affirmation as a task of teaching in the kindergarten context (e.g. Sæbbe & Mosvold, 2016), but we suggest that considerations of when and how to use praise differ between traditional recitation and discussion. We also consider it important to pay attention to possible negative effects of use of praise. Other studies have identified use of representations or concrete materials as an important aspect of the work of teaching mathematics in kindergarten (e.g. Sæbbe & Mosvold, 2020), but we suggest that there might be something specific about using concrete materials in discussions that needs further investigation. Finally, we suggest that the use of metaphors might be a part of the work of leading mathematical discussions in kindergarten that requires particular attention.

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