

ORCHESTRATION OF MATHEMATICAL ACTIVITIES IN THE KINDERGARTEN: THE ROLE OF QUESTIONS

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The aim of this study is to address the subtleties in the process of how kindergarten teachers orchestrate mathematical activities with a group of children. Drawing on a sociocultural perspective on learning and development, talk-in-interaction, emerging from naturally occurring data, has been analysed to get insight into how a kindergarten teacher orchestrate mathematical activities. The analyses show that the kindergarten teacher's use of questions, which we categorise into six groups, played a significant role in the orchestration of children's learning process. Through the use of questions and a pair of scales, verbal and non-verbal responses were engendered, relevant mathematical terminology was offered, and an inquiry approach towards measuring as a mathematical topic was initiated.

Keywords: kindergarten teacher, orchestration, teacher questions collaboration, inquiry

INTRODUCTION

During the recent years, mathematics in the kindergarten has been on the agenda with respect to the content of Norwegian kindergartens and their role in the society. In particular, this is emphasised in the curriculum for kindergarten (KD, 2006), where mathematics for the first time is explicitly mentioned as a topic with which children are supposed to be engaged. These societal demands of the kindergarten have put to the fore questions such as “What are we supposed to do with regard to mathematics in the kindergarten?” and “How do we do it?”.

A research project called Teaching Better Mathematics (TBM¹) has been initiated at the University of Agder. In this project, we are collaborating with several schools and kindergartens to promote learning and development in mathematics teaching. This paper reports from a case study situated within this project, analysing an activity in one kindergarten.

In this study, we use the notion of orchestration to describe a kindergarten teacher's actions when the children worked with measuring tasks. This includes an emphasis on the role of the kindergarten teacher's questions and comments to children's responses in the conversation. We also include the preparations made ahead of the sessions as being part of the orchestration, that is planned tasks, use of a pair of scales as well as the framing of the learning environment and number of children involved

¹ The TBM project is supported by the Research Council in Norway (NFR no. 176442/S20) and is managed by didacticians at UiA. The TBM project is based on collaboration between didacticians and teachers, kindergarten teachers and their leaders in two local councils and the local county where UiA is situated. The TBM project aims to promote development of mathematics teaching in schools and kindergartens, including participation in workshops arranged by didacticians at UiA, and research into these processes.

in the activity. Teachers' actions and arrangements during sessions are included in what Kennewell denotes as "supporting features" in teachers' orchestration:

The teacher's role is to orchestrate the supporting features – the visual cues, the prompts, the questions, the instructions, the demonstrations, the collaborations, the tools, the information sources available, and so forth... (Kennewell, 2001, p. 106).

From our collaboration with the kindergarten teacher, the following research question has been formulated: What roles do a kindergarten teacher's questions play in interaction with children when orchestrating mathematical activities?

THEORETICAL FRAMEWORK

In this study we adopt a sociocultural perspective on learning and development, that is we view learning as a social and situated process of appropriation where individuals make concepts, tools, and actions their own through collaborating and communicating with others (Rogoff, 1990, Säljö, 2005; Wertsch, 1998). In the process of appropriation, the role of tools is significant, in particular language in interaction with other psychological as well as physical tools (Vygotsky, 1978, 1986). The reason for adopting this theoretical position is our aim of describing and making sense of institutionalised interaction and learning activities among adults and children in the kindergarten. This perspective is useful for our emphasis on the orchestration of participation in social, mathematical activities. In adopting such a perspective when analysing our data, we aim at making sense of how adults and children are engaging in interaction by using verbal and non-verbal actions.

The experience the children do with measuring at various points and in different settings, altogether constitutes the basis from which the children are making shared meanings (Rogoff, 1990). By orchestrating a mathematical activity, the kindergarten teacher creates a learning environment for the children to engage and participate with ideas and arguments.

The theoretical stance of our study is in accordance with the TBM project's theoretical perspective in general (cf. Jaworski, 2007), where inquiry is a main theoretical notion. An intention from the didacticists' point of view in the project has been to study and promote development of mathematics teaching through inquiry (Jaworski, 2005; Wells, 1999). According to Wells (1999), inquiry is a process described as "a willingness to wonder, to ask questions, and to seek to understand by collaborating with others in the attempt to make answers to them" (p. 121). The nature of the collaboration with respect to the inquiry process is in accordance with how Wagner (1997) describes a co-learning agreement:

In a co-learning agreement, researchers and practitioners are both participants in processes of education and systems of schooling. Both are engaged in action and reflection. By working together, each might learn something about the world of the other. Of equal importance, however, each may learn something more about his or her own world and its connections to institutions and schooling (p. 16).

We acknowledge that didacticians (researchers) and teachers (practitioners) bring different expertise and engage in inquiry together to inform and develop their different practices.

In the study we aim to consider how the kindergarten teacher's orchestration promotes inquiry in learning and teaching. This is done through an emphasis on how the kindergarten teacher and the children explore mathematics together. The questions posed by the kindergarten teacher and the actions resulting from those questions are the unit of analysis in this study.

Studies have documented that whole-class interaction often is dominated by teachers' questioning to control and support their teaching (Barnes, Britton, & Torbe, 1986; Kirby, 1996; Myhill & Dunkin, 2005). Although several of these studies report that teachers also want to support students' investigations and reflections, their use of factual questions, or what Kirby (1996) calls simple questions, inactivated the students. Kirby argues that the way children interpret a story is heavily dependent on the kind of questions used by teachers. Kirby focused on the amount of information contained in the questions, and he found that use of simple questions was dominating. The lack of more complex questions used by the teachers prevented the children to make sense of the story text.

We want to argue with Roth (1996), that questions per se are not "universally good but need to be evaluated in terms of their situational adequacy" (p. 710). In accordance with what Roth argues, we are not treating the kindergarten teacher questions alike and categorise them indistinguishably. We are interested in the role these questions play, with respect to context, content, and children responses, "in student-centered, open-inquiry learning environments" (op. cit., p. 710).

ANALYSIS AND RESULTS

In this study we have collected empirical material through the use of video camera as well as field notes from one kindergarten. Our data consisted of a video tape of 27 minutes which was transcribed in full. Naturally occurring talk-in-interaction has been captured on an occasion when a kindergarten teacher has been engaging in measuring activities together with several children. In this case, the kindergarten teacher called Unni orchestrated a mixed-aged group of children who were participating in a measuring activity through interaction and communication. They were engaging with a pair of scales to measure which were heavier of various things with different size and weight.

In the activity, Unni interacted with six children 3-4 years of age, two girls and four boys. In Figure 1, a picture from the activity is presented.



Figure 1: The children and the kindergarten teacher engaging in the activity

Unni was a well experienced kindergarten teacher, with a background of more than ten years from working in a kindergarten. The measuring activity orchestrated in this case had previously been introduced to the kindergarten teacher in a workshop at the university. The introduction to the activity was made by didacticians at the university, but only as an example of an activity that might be possible to orchestrate in a kindergarten. No explicit guidelines were given with respect to how to orchestrate the activity and it was the total enterprise of Unni the measuring activity observed.

Thematically, we divided the data material into two parts. In the first part, the orchestration and interaction are about the weight of a toy crocodile and a box including plastic bears of various sizes and weight. The comparison of weights between these was made by all children both when holding them in their hands and with the use of a pair of scales. The second part concerned comparing the weight of small plastic bears of different sizes and weight. The children were challenged by the Unni to reason about the weight of the largest bear in comparison with the smaller ones. Both these activities were tightly orchestrated by Unni.

In analysing the transcribed material, we observed over 150 questions asked by Unni (cf. Table 1 below). We do not find the exact number of questions significant. Rather, we found it interesting to register that the communication and interaction between the kindergarten teacher and the children were fundamentally oriented around those questions and the children's verbal and non-verbal responses to them. With this as a background, we were able to categorise the questions into six different kinds of questions, and we analysed what kind of responses the various types of questions initiated. Some categories of questions were dominating more than others and some categories initiated more responses from the children than others. We are aware that others have categorised teacher questions as well (cf. Barnes et al., 1986; Myhill &

Dunkin, 2005; Roth, 1996; Wood, 1988). Roth, for instance, developed a typology of questions asked by one teacher with respect to their content. However, this typology of questions does not immediately fit with the categories we have forwarded. We focus on the role the questions played in the communicative practice and not exclusively on their content. Thus, our categories are elaborated with respect to the children's responses (Roth, 1996).

Table 1: Frequency table of the six categories of questions

Suggesting action	30
Open	71
Asking for argument	12
Problem solving invitation	12
Re-phrasing	19
Concluding	10
Total	154

In the following we will give a description of the six categories of questions. We will continue our analysis by going deeper into the role the different categories of questions played in the kindergarten teacher's orchestration. We consider what kinds of responses we observed from students, both verbal and non-verbal, to questions in the different categories.

Suggesting action: Questions within this category are characterised by their feature of initiating physical actions among the children, and not solely as initiating an oral answer. Typical questions in this category were: "Stein, can you feel?", "But do you think that it will go up if we put more into that?", and "Can you count them, and see if it is as many as this?".

Open: Almost half of the questions were categorised as open. Questions within this category inquired into the children's knowing with respect to the problem they studied. For instance, "Do you think this one weighs the most?", "How can we decide which one of them are the heaviest?", and "What has happened now?".

Asking for argument: This category includes the questions asked which follow up on an utterance from a child. The content of these questions includes that the child is asked to give reason(s) for his or her answer or opinion. Examples of this kind of questions are: "Why do you think that?", "How can we know that they have the same weight?", and "Why wasn't it equal this time?".

Problem solving invitation: Some of the questions included a problem or a challenge. These questions initiated opportunities for reasoning as well as being motivating with regard to experimenting and solving the problem. For instance, Unni

challenged the children by asking questions such as: “Is it possible to estimate how many such bears we need for them to be as heavy as a large one?”, and somewhat later “If I put two large bears into this one (puts two large plastic bears in one of the scales), what do you have to do to make it even?”. These questions are different from Suggesting action questions in that the former do not suggest any concrete actions to do to solve the challenge or problem.

Re-phrasing: At several occasions Unni re-formulated the children’s utterances into coherent sentences and questions. Very often the children responded with single words or short utterances, which were re-phrased as questions by Unni. Firstly, the questions set forth a mode of wondering among the children. When one boy called Tore said “this is heaviest”, Unni responded with “Do you think that one is the heaviest?”. Secondly, in these questions Unni took the opportunity to introduce new concepts, for instance the concept of weighing. When a boy called Arild said “That is the largest, therefore it is the heaviest”, Unni responded with a confirmation and a new question: “That is largest, but which one weighs the most?”. This is coinciding with Roth (1996), that teachers elicit specific content knowledge through questions.

Concluding: This category is used to describe those questions where the kindergarten teacher promotes a mathematical relationship or observation. The aim of those questions seem to be the children’s approval or for them to acknowledge a specific issue. For instance, in the following question Unni argues for adding more plastic bears in one of the scales: “That has to be heavier so that it can come further down, doesn’t it?”. Moreover, later she makes the point that “And then they have the same weight?”. The conclusions are given in the questions, but she wants the children to reason and conclude for themselves.

In the initial phase of working with the measuring tasks, Unni often asked *suggesting action* questions. In these questions, the children were asked to do actions with the pair of scales. In approximately all cases, such questions were followed by physical actions by the children instead of verbal responses. It is worth mentioning here, that it is possible to doubt if the questions are genuine questions (cf. Roth, 1996) or if they are invitations to what the kindergarten teacher Unni wants the children to do. However, those questions signal to the children that it is up to them to decide whether to do something or not.

In her orchestration, Unni’s use of these questions typically was followed by posing *open* questions. We observed that the *open* questions created attention to the practical activities that the children were involved in. For instance, when Unni asked “What happened now?”, the purpose with the question was probably to focus the children’s attention on the measurement activity. At several occasions, the *open* questions also served as a follow-up on questions from other categories. It seems as if the *open* questions were necessary to (a) keep their conversation going, (b) to engage and motivate the various children in their problem-solving efforts, and (c) to make them having a shared focus of attention.

The *open* questions challenged the children to respond verbally. Typically the open questions resulted in short replies such as “yes” or “no. Unni often continued with *re-phrasing* questions or *asking for argument* questions. By doing that, Unni seemed to have further initiated verbal responses from the children.

The *re-phrasing* questions were tools for adjusting the children’s use of mathematical language. Unni never explicitly corrected them, but through her re-phrasing, she emphasised the preferable terms to use. This issue is exemplified when Unni rephrased Arild’s utterance “And now they are equal of size” into “Are they equally heavy?”.

Re-phrasing questions were responded to by the children with affirmative replies such as “yes” or with comments such as “that” and pointing with fingers if they were asked to decide which of two things were heavier. In order to challenge students more verbally, Unni continued with *asking for argument* questions or by way of new *open* questions. When students responded successfully to *asking for argument* questions, it often led to *concluding* questions. If students did not succeed replying verbally to the *asking for argument* questions, Unni usually continued with some *open* questions, but also sometimes with *suggesting action* questions in her orchestration. To use those kinds of questions seemed not to have been a preferable choice by Unni, but questions she utilised when students did not manage to succeed with their argumentation.

We have already emphasised that the session we observed consisted of two parts. In the second part the children worked with the plastic bears and Unni started to use *problem solving invitation* questions. These questions usually invited the children to propose actions or to accomplish actions. Unni then followed up with *open* questions or *asking for arguments* questions which challenged the children verbally. Occasionally, she also used *suggesting action* questions to follow up the problem solving invitation questions. When a new sequence was initiated by a problem solving invitation question, the conversation usually fell into a similar sequence of questions as discussed above.

The *concluding* questions often occurred as a result of a previous discussion of a phenomenon. These questions occurred in three different settings. In one setting the questions concerned what they observed, such as “And when the scale is down, it is heaviest?”. In a second setting the questions concerned what the children were supposed to do. The questions included suggestions to actions, but the suggestions were assumed by Unni to be the correct thing to do. The question “Should we remove one from this scale too?” is an example of this setting. The third setting concerned mathematical conclusions. Questions used within this setting we interpret as being an important step in the kindergarten teacher’s efforts to facilitate the children’s process of appropriation. The question “So, if we take out two of the same size, we will restore balance again, if we take one from each?” exemplifies her effort to achieve a shared focus of attention among the children with respect to a certain mathematical

relationship. After different questions have been posed and responded to, the concluding questions may help the children to achieve a shared meaning for various terms and actions.

DISCUSSION

As argued above, the children's actions and utterances are divided into verbal and non-verbal responses. Concerning the children's responses to the questions, only a few questions resulted in inadequate response or no response from the children. Most often, they were able to give relevant verbal responses or they responded with pointing gestures or actions with respect to the given artefacts in order to answer the kindergarten teacher's questions.

The verbal responses were often supported by different types of gesturing. The children did rarely answer questions with complete sentences. This is, however, not surprising, thinking of their age (3-4 years). This observation might also be explained by studying the way the kindergarten teacher posed the questions. Many of the questions were formulated in ways that initiated short responses. On the other hand, when the kindergarten teacher used questions that from our perspective initiated more elaborated responses, the children still gave short responses.

Since the questions were so closely linked to the practical activity, the children were able to respond to several questions in a non-verbal way. They answered lot of questions by pointing, shaking their heads or by moving the artefacts. For instance, in working with balancing the scales, the kindergarten teacher asked about how they could lift one of the scales so that they restore balance. In stead of verbally answer the question, Kari put a brick in the highest scale. Occasionally the children also combined verbal and non-verbal responses. This observation, we argue, signifies the importance of including physical artefacts as tools in orchestrating mathematical activities.

The complexity in the interaction is illustrated in the kindergarten teacher's use of different categories of questions, and we observed a sequence in her use of these categories. Such a sequence typically was initiated by using a *suggesting action* question (occasionally *problem solving invitation* question). Then she continued with an *open* question, followed by either an *asking for argument* question or a *re-phrasing* question. The sequence ended with one or several *concluding* questions. This finding that the kindergarten teacher has an aim for the activity which was supposedly reached by her sequencing of questions coincides with Roth (1996). He also found that the teacher controlled the communicative practice among her students, not through a classical IRE² sequence, but by means of a sequence of queries.

² IRE is an abbreviation of a communicative pattern found in traditional classrooms: The teacher takes Initiative, the students give Response, and the teacher Evaluates the response

We argue that the kindergarten teacher played a significant role in the children's learning process. Kirby (1996) claims that lack of complex questions prevented the children to make sense of mathematical ideas. However, we believe that the kindergarten teacher, in her orchestration tied the mathematical ideas together through her frequent use of questions, in a way that made it possible for the children to participate. Thus, the children were involved in a joint activity where they achieved shared foci of attention, and opportunities for achieving shared meanings were given (Rogoff, 1990; Wertsch, 1998). It seemed as if that the kindergarten teacher expected short answers and never went empty for new questions to ask in order to bring the learning process forward.

An aim of the TBM project is for the kindergarten teachers' to develop inquiry as a way of being in teaching. Indication of this development is in Jaworski (2007) described in the following way: "So, developing inquiry as a way of being involves *becoming, or taking the role of, an inquirer; becoming a person who questions, explores, investigates and researches within everyday, normal practice*" (p. 127). We argue that the kindergarten teacher's orchestration of the activity, with her use of questions to promote investigation and reasoning, is exemplifying inquiry as a way of being. Our observations suggest that questions represent an effective tool in order to engage a group of children in learning activities. In accordance with Kirby's (1996) findings, the children did not pose questions. Therefore it might be objected whether the children made sense of the mathematical issues in this case. However, we believe that the joint participation and collaboration created a mathematically goal-directed activity, from which the children made shared meanings for concepts, terminology, and actions. From an analytical point of view, not every question may be characterised as genuine questions. For instance, some of the *suggesting action* questions and *concluding* questions are hidden suggestions or instructions. This is in accordance with what Myhill and Dunkin (2005) found, that teachers often "had a set answer in mind" (p. 424) even when they asked open questions. Nevertheless, it is likely to assume that the children perceived these questions as real since they both verbally and non-verbally actively participated in the activity. Our study thus shows that through the use of questions, the kindergarten teacher created a milieu of inquiry (Wells, 1999), and they were a substantial part of her orchestration.

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