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► **To cite this version:**

Ingvald Erfjord, Martin Carlsen, Per Sigurd Hundeland. Characterising the mathematical discourse in a kindergarten. Eleventh Congress of the European Society for Research in Mathematics Education (CERME11), Utrecht University, Feb 2019, Utrecht, Netherlands. hal-02414867

HAL Id: hal-02414867

<https://hal.science/hal-02414867>

Submitted on 16 Dec 2019

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Characterising the mathematical discourse in a kindergarten

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In this study we investigate the mathematical discourse in a kindergarten. The mathematical learning activity engaged with was initially designed by researchers for 5-year-olds, and the kindergarten teacher orchestrated the mathematical activity. Observational data was quantitatively analysed by measuring how time and talk were distributed between the kindergarten teacher and the children. We also analysed whether the talk was focused on mathematics or not. Our analysis shows that the time elapsed during the activity was distributed unequally, the nature of the participants' utterances shared both similarities and differences, while the engagement nurtured upon the kindergarten teacher's request varied from each of the requests. Based on these results we characterise the mathematical discourse and hypothesise about the children's potentials for mathematics learning.

Keywords: Discourse, inquiry, kindergarten, mathematics, playful learning.

Introduction

Researching teaching and learning of mathematics in a kindergarten setting has been gaining improved focus over the last decade. Since the establishment of the early years mathematics research group at the 6th Congress of the European Society for Research in Mathematics Education in Lyon in 2009, a multitude of research foci have been launched and 50-100 research studies have been conducted (see CERME proceedings, www.mathematik.uni-dortmund.de/~erme). This is not to neglect journal articles published in the same period as well as before 2009. Early years mathematics has gained its place as a research field with mathematics education research also due to the four POEM conferences we have seen so far (POEM - A Mathematics Education Perspective on early Mathematics Learning). A huge portion of the conducted studies have been qualitative in nature, as case studies have been conducted, observations and interviews have been made (Levenson, Bartolini Bussi, & Erfjord, 2018). This study is an attempt to broaden the qualitative research scope and include quantitative aspects of mathematics discourse in a kindergarten context.

The aim of the analyses made in the current study is thus to quantitatively characterise the mathematical discourse evolving as a kindergarten teacher (KT) orchestrates a mathematical activity for her five-year-olds. In the analysis we seek to develop an analytical approach which quantifies the collected qualitative data. We use the term mathematical discourse in line with Sfard (2007), as a type of communication featuring mathematical words that “bring some people together while excluding some others” (p. 573). According to Sfard, a mathematical discourse has the features called visual mediators, narratives, and routines as well. However, in the current study we focus at the verbalisations made by the KTs and the participating children. The results of our analysis will be discussed in light of the framework of mathematics discourse in instruction (MDI), developed by Adler and Ronda (2015), which heavily build on Sfard's (2007, 2008) work. For the present study we have formulated the following research question:

What characterises the mathematical discourse in a kindergarten in which a kindergarten teacher and five-years-old children engage with a planned mathematical learning activity?

In our analysis we have particularly focused at three dimensions: (1) the distribution of time in the activity; (2) the nature of the participating persons' utterances; and (3) the engagement nurtured through the KT's initiatives, requests, and prompts. Our focus at adult-child interactions has been studied elsewhere (e.g. Carlsen, Erfjord, & Hundeland, 2010; Dovigo, 2016; Vogel & Jung, 2013). Dovigo (2016) studied argumentation as a basis for collaborative learning and problem solving in a preschool setting. Dovigo adopted a sociocultural approach in his analysis, compared teacher–children talk and peer-talk, and investigated the role of argumentation in empowering children's collaboration and problem solving through discursive practices. Results from quantitative and qualitative analyses show that argumentation is effective in cultivating shared and critical thinking amongst the children.

The mathematical activity that was orchestrated by the KT (one of many) was designed by researchers in mathematics education (the authors of this paper among others) in collaboration with the KT (among others), as part of the research and development project called “The Agder project”¹ (AP). This is why we use the term planned mathematical learning activity in the research question.

These planned mathematical activities were designed based on the principles of playful learning and inquiry approach to the learning of mathematics. Playful learning as a construct comprises free play (child-initiated and child-directed play) and guided play (adult-initiated and child-directed play). In AP we drew on the principle of guided play as the KTs were empowered to orchestrate and guide the children's play in the mathematical activities in purposeful directions in order to plausibly reach aims for the activities. Furthermore, The KTs functioned as catalyst for the interest, curiosity, engagement, and mathematical sense-making of the children (cf. Weisberg, Kittredge, Hirsh-Pasek, Golinkoff, & Klahr, 2015). Adopting inquiry as an approach to the learning of mathematics is in accordance with Jaworski's (2005) inquiry as “a way of being in practice” (p. 103). Inquiry as a way of being is empowering when five-year-olds and their KT interact to achieve insights in mathematics. By seeking answers to mathematical prompts and questions, the children's curiosity and excitement are nurtured and met.

Mathematical Discourse in Instruction

Adler and Ronda (2015) developed the MDI framework to analyse the mathematics made available for students to learn in the classroom. The framework was developed for a South African classroom setting, deviating from a Norwegian kindergarten context. We have thus slightly adapted the framework in order for us to purposefully employ this framework in our analyses of orchestrations of mathematics activities. However, the main components are adopted in our use of the framework. But as will be seen, we have adapted the definitions of these components to also encompass a Norwegian kindergarten context.

According to Adler and Ronda (2015), it is important to focus on what mathematics students are supposed to learn, when analysing teaching. Thus, the object of learning, e.g. a concept, procedure,

¹ The Agder project is funded by the Research Council of Norway (NFR no. 237973), The Sørlandet Knowledge Foundation, The Development and Competence Fund of Aust Agder, Vest Agder County, Aust Agder County, University of Agder and University of Stavanger.

algorithm, is the starting point for the MDI framework. In our context and analysis, acknowledging and accommodating the social pedagogy tradition of Norwegian kindergartens' enterprise, we use the concept of intention to address what the children are supposed to meet and make experiences of in the mathematical activities. Further, Adler and Ronda (2015) argue that the mediational means used in teaching to reach the object of learning, are exemplification (examples and tasks), explanatory talk (naming and legitimations), and student participation. We believe learning takes place in social, communicative settings, in which children and adult(s) actively participate, engage, and argue in interaction. Hence, it is of importance to consider children's possibilities to talk in the orchestrations, their opportunities to "speak mathematically and to verbally display mathematical reasoning" (Adler & Ronda, 2015, p. 245).

The mediational means of exemplification manifests itself as examples and tasks. Examples used in mathematics teaching/orchestration serve the purpose of being a representative of a larger class, one particular case of that class from which it is possible to generalise (Zodiak & Zaslavsky, 2008). Deliberate use of examples is important to reach the intention/object of learning. Tasks are also commonplace constituents of mathematics teaching/orchestration. Tasks are given by the teacher/KT to bring to the fore certain mathematical properties, actions etc. Tasks are thus what the children are supposed to do with the examples given (Adler & Ronda, 2015).

The mediational means of explanatory talk comprise what is to be done and known, that is to name and legitimate the focus and content of the talk between the teacher/KT and the children. To address this, Adler and Ronda (2015) coin the terms naming and legitimation. Naming is "the use of words to refer to other words, symbols, images, procedures or relationships" (p. 244). Naming may be either colloquial, non-mathematical everyday language, or mathematical, either mathematical words used or reading strings of symbols (Ms) or formal mathematical language used (Ma). Legitimation comprises four domains: mathematical, non-mathematical, curriculum and teacher. Within the mathematical domain there are local (L) criteria (specific case, convention) and general criteria (partial (GP) and full (GF) that give authority. Within the non-mathematical domain there are also criteria that give authority, called visual (V), positional (P), assigning the authority to the speaker, and everyday (E) knowledge and experience. The significance of addressing all these criteria is, according to Adler and Ronda (2015), "the opportunities they open and close for learning" (p. 244).

The KT's utterances will be analysed according to the levels in the MDI framework (cf. Adler & Ronda, 2015), where level 1 is a type of mathematical discourse in which the children contribute with answers to yes/no questions or single words to the KT's unfinished utterances. Level 2 is a type of mathematical discourse in which the children contribute with answers to what/how questions in phrases/sentences. Level 3 is a type of mathematical discourse in which children contribute with answers to why questions and present ideas and where the KT revoices/confirms/asks questions (cf. Adler & Ronda, 2015).

In our discussion we adapt the MDI framework in order to analyse the KTs' orchestration of mathematical activities. Thus, not all facets of the MDI framework will be used in the discussion. The reason for our adaptation is that the MDI framework is developed to analyse mathematics teaching in (South African) schools. The Norwegian kindergarten context differs significantly from that school context. As will be seen in the analysis, to approach the intention/object of learning of the mathematical activity, the KT exemplifies by the use of examples, use of tasks made explicit

through questioning, and explanatory talk. The children participate in the interaction with the KT, question and argue for their opinion(s).

Our analytical approach

In this study we collected video data from the orchestration of a mathematics activity by one kindergarten teacher. The activity involved five five-years-old children in this kindergarten who participated in AP, selected by the KT. The studied KT and children were chosen out of convenience, based on the consideration that the only criterion for selection was that the observed KT and children had to participate in AP and voluntarily participate in this specific study.

In order to analyse the mathematical discourse emerging from the KT's orchestration of a mathematical activity, we developed an analytical tool that fitted our purpose of quantifying qualitative data. Quantification of qualitative video data has also been studied by Vogel and Jung (2013), however from a slightly different perspective. The first step of our analytical process was that we agreed upon making 'quantification of qualitative' data the main focus of our analysis. With this idea in mind, the second step of our analysis continued as two of the researchers met and discussed ways of making this quantification. These two researchers agreed that use of time was a critical element in the orchestration, who had the floor? Were any questions asked, and by whom? Were the questions mathematical ones or not? What other comments were made, and by whom? Were these comments mathematical or not? etc.

The result of that meeting was submitted to the third researcher, who had not been taking part in the discussions so far, comprising a third step in our analysis. This researcher critically scrutinised the preliminary analytical tool, asked critical questions and made modifications to the tool.

All three researchers met for the fourth step of our analysis as we refined the analytical approach, agreed upon the various dimensions necessary to scrutinise in order to analyse the mathematical discourse in the kindergarten, as well as pinpointed sub-categories within the three dimensions. The idea behind our analytical approach is to steadily funnel down to the core of our analysis. The distribution of time is seen as a first attempt to separate the various elements of the activity. Secondly, we discriminate between what we call verbal mathematical contributions and non-mathematical or colloquial contributions. Thirdly, we have chosen to make a deeper analysis of those verbal contributions in which mathematics is focus, what Sfard (2008) would label a mathematical discourse. Our analytical approach is summarised in the following table (Table 1):

Distribution of time between the KT and the children		
Who	Number of minutes	Description of category
KT active		Informing, Demonstrating, Explaining, Exemplifying
Dialogic communication		Questions and prompts from KT and answers from children
Children active (KT interference tolerated)		The children work with concrete materials, explore mathematical relationships «on their own»
Verbal utterances		
Who	Mathematical (#)	Non-mathematical (#)
KT		
Children		

Mathematical engagement nurtured					
Initiatives from KT	Child 1	Child 2	Child 3	Child 4	Child 5
1					
2					
...					
N					

Table 1: The analytical approach to quantification of qualitative data

Analysis of the mathematical discourse associated with ‘The secret bag’

The mathematical activity called ‘The secret bag’ was orchestrated by the KT Tone (pseudonym). The activity addresses geometrical shapes of both two and three dimensions and an in-transparent fabric bag. The KT and the children talked about and discussed the various geometrical shapes, and they talked about the connections between two-dimensional shapes and three-dimensional shapes, as some two-dimensional shapes may be turned into three-dimensional ones and vice versa. Continuing from this, the KT put all the shapes in the in-transparent bag, and let one child at a time, hold his/her hand into the bag, pick one of them and tactilely reason what shape the picked one has. As seen in Table 2, the KT holds the floor for approximately 1/3 of the total time used, the children are active discussing more or less on their own for about 15 % of the time. About 50 % of the time was used for dialogic communication between the KT and the children.

Category	Distribution of time
KT active	00:07:16
Dialogic communication	00:10:54
Children active (KT interference tolerated)	00:04:11

Table 2: Distribution of time between the KT and the children

Concerning the verbal communication going on in the activity, we found that the KT made 125 mathematical utterances and 99 non-mathematical utterances. The children contributed with 103 mathematical utterances and 86 non-mathematical utterances. An utterance is here viewed as an instance of speech. However, the non-mathematical utterances enable the mathematical utterances to emerge. Thus, all utterances contribute to the ongoing mathematical discourse (cf. Sfard, 2007, 2008).

Verbal utterances			
Who	Mathematical (#)	Non-mathematical (#)	Sum
KT	125	99	224
Children	103	86	189

Table 3: Categorisation of utterances

In this study we are occupied with the KT’s utterances that we characterise as mathematical and the verbal engagement nurtured amongst the 5 children involved. Upon the KT’s verbal utterances, we counted the number of contributions of the various children, see Table 4.

	Erik	Ivar	Ida	Mari	Nina	>1	Sum
Number	62	29	23	24	22	29	189

Table 4: Number of verbal contributions distributed over the children

We further registered the number of children responding to the KT's questions and prompts, thus we see this number as a measure of the mathematical engagement nurtured, see Table 5. Three questions from the KT were not responded to at all, and none of questions/prompts engaged all five children. At 46 occasions it was only one child responding to the KT's question/prompt. However, each child might contribute with several responses to the initial question/prompt. Thus, the total number of responses in Table 5 (120 responses) is less than the 189 verbal contributions mentioned above.

# of children engaged	0	1	2	3	4	5	Sum
Frequency	3	46	23	4	4	0	77
# of children responding in total	0	46	46	12	16	0	120

Table 5: Children responding to the KT's questions/prompts

Adopting an inquiry approach to the orchestration of mathematical activities in kindergarten, will plausibly create mathematical engagement amongst the children. We thus further scrutinised each of the 77 contributions of the KT that engaged the children mathematically, and we analysed the mathematical discourse that these contributions initiated according to the levels of discourse in the MDI framework (cf. Adler and Ronda, 2015). From this analysis we found that 49 mathematical discourses were at level 1, 24 of the discourses were at level 2 and four discourses were at level 3, see the right-hand column of Table 6.

# of children engaged	1	2	3	4	Sum
# of mathematical discourses at Level 1	31	14	2	2	49
# of mathematical discourses at Level 2	14	8	0	2	24
# of mathematical discourses at Level 3	1	1	2	0	4
Total	46	23	4	4	77

Table 6: Number of children involved versus the levels of mathematical discourse

Amongst the 49 mathematical discourses at level 1, 31 engaged only one child, 14 of those 49 discourses at level 1 engaged two children, 2 discourses engaged 3 children and 2 discourses engaged four children. From Table 6 we also observe that approximately 64 % of the mathematical discourses were at level 1, and 36 % were at level 2 & 3. We also observe that rarely more than 2 children were engaged by the KT's questions and prompts, 69 (46 + 23) out of the 77 mathematical discourses, and in those occasions 45 were at level 1 and 22 at level 2 and only two discourses were at level 3.

Examples of the KT's questions and prompts that we analysed as initiating a mathematical discourse at level 1 were: "Are all the edges (of the rectangle) of equal length?" and "Is it (the rectangle) two dimensional?" Examples of the KT's questions and prompts that we analysed as initiating a mathematical discourse at level 2 were: "What is this (a sphere)?" and "What is your thinking with respect to that one (a cone)?" Examples of the KT's questions and prompts that we analysed as initiating a mathematical discourse at level 3 were: "Why is that a rectangle?" and "Why does this quadrilateral (a square) have another name?"

Discussion

We have addressed the question: What characterises the mathematical discourse in a kindergarten in which a kindergarten teacher and five-years-old children engage with a planned mathematical activity? *Firstly*, the mathematical discourse analysed is dominated by the KT. She holds the floor

on individual basis for about 1/3 of the elapsed time for the whole activity. She is also dominating the dialogic communication going on, a category comprising approximately 50 % of the elapsed time. This result is also documented by Dovigo (2016). *Secondly*, we observe that the distribution of verbal utterances amongst the KT and the children is fairly equal, both regarding utterances categorised as mathematical and utterances categorised as non-mathematical. However, we also observe that the children do not contribute equally to the mathematical discourse. Erik is dominating and the other four children are contributing approximately at the same level. *Thirdly*, the mathematical discourse is characterised by engaging only one or two children. Additionally, 64 % of the mathematical discourses were at level 1 and 36 % at level 2 and 3 according to Adler and Ronda (2015).

The sparsity of occasions where three or four children were engaged, and at the same time engaged in a mathematical discourse at level 2 and 3, we hypothesise has consequences for the mathematical learning potential in this orchestrated mathematical activity. According to Sfard (2007), “Learning mathematics may now be defined as individualizing mathematical discourse, that is, as the process of becoming able to have mathematical communication not only with others, but also with oneself” (p. 573). We thus hypothesise that the children in this activity have limited opportunities to individualise the mathematical discourse occurring.

We took the KT’s questions and prompts as point of departure in our analysis, and scrutinised the mathematical discourse associated with these various questions and prompts. The mathematical discourse was then analysed according to the levels of Adler and Ronda (2015) regarding children’s participation. From this analysis, we came to the result communicated in Table 6 above. Our initial hypothesis was that it seems reasonable to argue that the levels of children participation comprise an increasing opportunity for learning. Thus, the potential of learning associated with a level 3 mathematical discourse is more promising than mathematical discourses at level 2 and level 1 respectively. Our analysis shows that most of the mathematical discourse was at level 1 (64 %). From the analysis we argue that the KT often initiated a mathematical discourse at level 1 through asking a yes/no question. However, these mathematical discourses evolved into mathematical discourses at level 2 and level 3 in several occasions. Thus, mathematical discourses that from the outset may seem to have a limited learning potential evidently may improve into mathematical discourses at levels comprising a higher mathematical learning potential.

We also find that the KT adopts an inquiry approach to mathematics teaching and learning (cf. Jaworski, 2005), due to her mathematical questions and prompts. However, how to engage the children in mathematical inquiries is a different matter. An implication from our study is thus how to empower the children’s inquiry by discussing more between themselves. More research regarding what characterises mathematical activities that empower children’s own inquiry into mathematics is needed.

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