Engaging children in mathematical discourse: a kindergarten teacher's multimodal participation

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This article reports from a case study which investigates a kindergarten teacher's multimodal participation in a teaching-learning activity involving addition and counting. By multimodal participation the kindergarten teacher engages nine children (age 4.9–5.9) in mathematical discourse and supports their opportunities for learning. Implications for practice are that kindergarten teachers (and school teachers) can benefit from being consciously aware of the affects their bodily actions have on children's mathematical reasoning and how they can engage children in mathematical discourse without having to "teach" (i.e., tell) children mathematical concepts and relations. The article also considers how kindergarten teachers can prepare for a smooth transition to school by introducing children to mathematics through semi-structured activities.

In the last year of Norwegian kindergarten, children (age 4.5–6.5) are about to make a transition from an institution where play, care, upbringing and learning are the main foci, into an institution which focuses more on their academic learning. This transition may be challenging for many children (Lillejord et al., 2017) and it is important to get insight into how to prepare for a smooth transition. This article reports on a case study which focuses on the manner in which a kindergarten teacher (KT) engages with 4.9–5.9-year-old children in a mathematical problem, involving addition and counting, in the context of pre-designed mathematical activities aimed to prepare children for school. The KT's mandate is to structure the discourse around mathematics, which is quite different from engaging in a spontaneous floating conversation in an "everyday situation" in kindergarten.

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Children's opportunities to take part in mathematical discourse[1] are considered important in learning mathematics, both in kindergarten (Dovigo, 2016), and in school (Mercer, 2000; Rojas-Drummond & Mercer, 2003; Wells, 1999). However, in activities where the school teacher or KT have a pedagogical aim, it may be difficult to balance teacher talk and child talk (O'Connor & Michaels, 1996; Dovigo, 2016). Research considering how KTs may facilitate children's opportunities to participate in mathematical discourse is sparse. The rational for this study is to contribute to this area of research by investigating how a KT engages children in mathematical discourse and supports their opportunities for learning by her multimodal participation (i.e. her use of various semiotic means).

This article addresses the following research questions:

What characterises the KT's multimodal participation in a teaching-learning activity involving addition and counting?

How does the KT's multimodal participation supports discourse and children's opportunities for learning?

A cultural-historical perspective

In this article, teaching and learning are conceived as an interconnected whole – a dialectical, mediated activity where mathematical ideas (among others) are mediated through semiotic means (e.g. language, artefacts, gestures and signs) (Radford, 2013; Vygotsky, 1987). Although language is essential for developing abstract thoughts, the multimodal nature of cognition has gained attention in 21st century research (Radford, 2009, 2013; Radford, Edwards & Arzarello, 2009; Roth, 2001). Radford's (2013) theory of knowledge objectification emphasises how gestures, bodily actions, artefacts, mathematical signs and speech work together in the constitution of mathematical reasoning. In Radford's theory, activity is conceived as a process, or a system of relations, which unfolds through human actions. Activity comprises both inner (cognitive) and outer (material) processes and is something "real" that can be observed. In Radford's theory, learning is viewed as an objectification process (i.e. is related to the object of the activity) where knowledge is mutually constructed i.e. mediated through semiotic means. Learning is theorised as "social processes of progressively becoming critically aware of an encoded form of thinking and doing – something we gradually take note of and at the same time endow with meaning" (ibid., p. 26). This research study adopts Radford's (2013) cultural-historical perspective to study the dynamics of a mathematical teaching-learning activity in kindergarten.

The term "discourse" is complex and used in a variety of ways. In this article the terms discourse, dialogue and conversation are used interchangeably and in line with Gee's (2008, 2011) definition of discourse, which is "language in use or connected stretches of language that make sense" (Gee, 2008, p. 154). My epistemological stance resides in Radford's (2013) cultural-historical perspective and theory of knowledge objectification, and I use Radford's definition of activity to describe the teaching-learning interaction that unfolds in the kindergarten group examined in this study. However, I see discourse, as defined above, as a subset of activity, and is used in this article to describe how the children are promoted to use language when they engage in the activity (without ignoring their use of other semiotic means).

Much of the literature below on how to engage children in mathematical discourse is taken from school setting where teaching-learning activities are often more structured than in kindergarten, and which points to challenges that may arise in such teacher-led activities.

How to engage children in mathematical discourse

Children's opportunities to take part in mathematical discourse are important in learning mathematics but distinct forms of discourse facilitate different learning opportunities. Dialogic inquiry (Wells, 1999) and exploratory talk (Mercer, 2000) are two (not dissimilar) constructs which describe perceived effective ways for participants to interact, to reason and to solve problems together. Developing effective discourse for learning, however, is not a straightforward process. In teacher guided activities it is challenging to find a balance between teacher-talk and child-talk (O'Connor & Michaels, 1996; Dovigo, 2016). Teachers may experience tensions between overseeing the conversation and promoting the children to participate in the discourse. O'Connor and Michaels (1996) argue that an aim of teaching is to nurture children's talk and promote them to take part in the ongoing discourse, whilst simultaneously focusing learning and discourse around specific content.

Questions are regarded as important for engaging students in mathematical conversations and give positive learning outcomes (Kirby, 1996; Roth 1996; Rojas-Drummond & Mercer, 2003; Myhill & Duncan, 2005; Carlsen, 2013). However, some question strategies can help children to participate, others can limit children's participation in the ongoing discourse. If questions are used for checking children's knowledge or overemphasise factual or procedural knowledge, they can promote an unproductive discourse for learning (Kirby, 1996; Roth, 1996). Both "closed questions" (inviting short factual/procedural responses) and "open

questions" (inviting longer and possibly elaborate responses, often with no predetermined answer) are found to initiate the well-known teacher led discourse pattern called the IRE-/IRF-exchange (initiation-response-evaluation/follow up) (Wood, 1992; Wells, 1999; Rojas-Drummond & Mercer, 2003). This exchange has both been criticised and appreciated as a pedagogical tool. When criticised (Wood, 1992) the initial teacher question is often a closed question with a "correct answer". This type of exchange often serves only to check pupils' knowledge, which is not necessarily productive for learning. Wells (1999) agrees that the triadic dialogue can be counterproductive for learning but argues that IRF exchanges can also serve as a useful pedagogical tool to achieve co-construction of knowledge. The quality of this exchange relies in the underlying expectations and goals of the teacher. Similarly, Rojas-Drummond and Mercer (2003) argue that IRF exchange can help to guide children's learning, especially if the teacher follows up with "why-questions" which promote students to reflect on their responses. Another way to follow up children's contributions and promote them to think further on their ideas is by re-voicing (O'Connor & Michaels, 1996). Re-voicing is defined as when a participant repeats another participant's contribution (or parts of the contribution). O'Connor and Michaels argue for the usefulness of this type of follow up for engaging students in the classroom discourse, to focus attention to key-points and thus facilitate learning possibilities.

Mathematical learning activities in Norwegian kindergartens are often organised in ways where KTs and children interact in informal and semi-formal settings, and where mathematical ideas come to play through conversation and the use of artefacts (Erfjord, Hundeland & Carlsen, 2012). Dovigo (2016) investigated how participation in different types of conversations (peer-talk and child-teacher talk) influenced preschool children's learning opportunities. The study showed that children had richer opportunities to contribute in peer-talk. In child-teacher talk, the KT talked more than the children. In peer-talk the children asked more questions (including open questions). However, the children's abilities to build arguments were limited in peer-talk. Teacher guidance helped the children to elaborate their argumentation and to improve their abilities to collaborate.

This study investigates how a KT engages with kindergarten children in an addition problem, where the children use various counting strategies to solve the problem. Children's counting strategies to solve addition problems are well documented (Baroody & Purpura, 2017; Carpenter & Moser, 1982; Fuson, 1992), and at least three different counting strategies for addition have been identified: 1) The "counting-all" strategy has been identified as the most common, and which children typically use

first. After having identified the cardinality of the two sets (by counting each of the sets), children find the sum of the two sets by starting from the beginning and count all items together as "a whole". 2) A more sophisticated strategy is "counting-on". After having counted and found the cardinality of the two sets, children take the number of items in the first set as a point of departure, and then count further on the other set of items. 3) Using the "counting-on from largest" strategy children take the number of items in the largest set as a point of departure and count further on from that. Carpenter and Moser (1982) observed that, even if children are capable to use the counting-on procedure, the children nevertheless often used the counting-all procedure. They argue that children can be encouraged to use the counting-on procedure if there are no physical artefacts available for the children to manipulate.

Setting

This case study is situated within a Norwegian research and development project called the Agder Project. The project aims to develop a curriculum that prepares Norwegian 5-year-olds for school and to investigate the processes of teaching and learning that unfold when the curriculum, in the form of pre-designed mathematical activities, is implemented by the participating KTs. The study reported here took place in one of the kindergartens in the project, where the KT implemented a mathematical activity called *Tower building*, which was designed to provide the children with experience in counting, comparing sets of numbers and introductory addition. In the written activity description, the KT is requested to introduce the activity using a doll called Super Sigurd, which the children are familiar with. Super Sigurd has built three towers, and he thinks that he has 20 building blocks altogether, but he is not quite sure (the three towers consist of 5, 7 and 8 building blocks). The KT is requested to start the activity by asking the children if they can help Super Sigurd to figure out how many building blocks his towers consist of altogether. The segment examined in this article is selected from the introduction of the activity, where a KT and a group of preschool children (age 4.9–5.9 years, three boys and six girls) are working with the addition problem. The KT is an experienced KT and the children are familiar with similar whole-group learning activities.

Methodology

To capture the dynamics of teaching and learning mathematics in kindergarten I used qualitative methods within an interpretative paradigm.

The segment examined in this article is selected from data collected in four kindergartens at four occasions (16 sessions altogether) during the school year 2016/2017. All observed sessions were video recorded and field notes were written. The video data from all observed sessions were separated into parts (segments) and organised in tables recording the times and descriptions of the interactions. The description included utterances and were supplemented by video stills of observable actions. For further analysis, segments were selected from these descriptions based on three criteria: 1) problem-solving interactions 2) the children's contributions to mathematical ideas, mathematical arguments, explanations or reflections 3) eagerness from children to participate.

The segment examined in this article was selected because the children had ample opportunities to suggest and explain strategies to solve the problem and the children eagerly participated in the discourse. The selected segment was transcribed[2] and then analysed from a cultural-historical activity theory perspective, where *activity* (the process that unfolds when the participants interact) is the unit of analysis. Using Vygotsky's (1987) dialectic approach, I always considered two subsequent turns in relation to one another, or I considered a turn in relation to the following activity (several turns in a row). For example, when the KT asks "How can we figure out how many there are altogether?", I argue that the KT invites the children to contribute with different strategies to solve the problem because the children, in the following activity, eagerly contribute with different strategies. The analysis was accomplished through an iterative examination of the data (the segment). Videoclips from the whole-group session and extracts from the data analysis were watched and discussed with four research colleagues in the project and were important for the final interpretation of the interactions in the segment.

Results

Prior to the segment analysed below, the KT and the children count each of the three towers and conclude that the yellow, blue and red towers consist of five, seven and eight blocks, respectively. The KT writes the numbers of blocks on small pieces of paper and lays them in front of each tower and, with a questioning look, initiates an interplay with the children.

92	KT	How can we figure out how many there are altogether? ((Questioning look))
93	Leo	((Puts his finger to his mouth)) Hmm ... ((Then he raises his hand in the air. His facial expression changes from a questioning look into an "understanding look" in the moment that he raises his hand))

94	KT	Leo
95	Leo	((Leans forward and puts his finger on top of the red tower)) What about ... ((He stops and pauses before going back to his place))
96	Lily	((Puts her hand in the air))
97	KT	Lily
98	Lily	Twenty-one
99	KT	Is it twenty-one? ((Questioning look))

The original problem was formulated as a question to the children on helping Super Sigurd to figure out how many building blocks there were altogether. In line 92 the KT asks "How can we figure out how many there are altogether?", which changes a closed question into an open question. This question invites the children into a conversation about different strategies they may use to solve the problem.

Figure 1. *The KT's facial expression and body positioning when she asks; "How can we figure out how many there are altogether?" in line 92*

Figure 1 illustrates the KT's facial expression and body positioning at the time of line 92 when she invites the children to contribute with different strategies to figure out how many building blocks there are altogether. The KT knits her eyebrows, tightens her mouth and rests her head in her hand. I interpret her facial expression as a "questioning look", which communicates that the task is not easy, and that the children need to think carefully about how to solve the problem and suggest solutions.

Figure 2 illustrates Leo's stance when he says "Hmmm ..." in line 93. Leo puts his index finger to his mouth and he knits his eyebrows when he says "Hmm ...". His facial expression is similar to the KT's facial expression, and the utterance "Hmm ..." may indicate that he thinks carefully about the problem. Leo does not orally express what he thinks, but his facial expression communicates that he ponders.

Figure 2. *Leo's stance when he says "Hmmm…" in line 93*

A second later Leo's facial expression suddenly changes from a "questioning look" to an "understanding look" when he raises his hand in the air. The KT invites Leo to explain his idea (line 94), however Leo seems to forget his idea because he sits down again (line 95). Then Lily expresses that she wants to contribute (line 96) and the KT invites Lily to explain her idea (line 97). Lily suggests "Twenty-one" (line 98), and the KT responds "Is it twenty-one?" (line 99), without any marked rising intonation, which might indicate excitement, at the end. The KT takes Lily's suggestion, re-formulates it into a question and sends it back to the group for consideration. The KT continues to lean forward, with her hand in her face and with the same facial expression (questioning look). I interpret the KT's response as indicating that she does not want to explicitly evaluate Lily's suggestion. She does not say whether the suggestion is correct or incorrect. By re-voicing Lily's suggestion, the KT kindly appreciates Lily's contribution, and she also shares Lily's idea with the other children. However, by re-formulating the suggestion into a question, she sends it back to the group for a re-consideration. After Lily has shared her idea, another girl (Fia) offers a different suggestion:

100	Fia	We can count.
101	KT	Maybe we can count? ((He moves her hand away from the face, down in her lap, she straightens her back and makes an excited facial expression. She emphasis "count" with a marked rising intonation))
102	Childr.	Yes! ((Several children respond simultaneously))
103	John	It is twenty-six
104	KT	((Questioning look)) Is it twenty-six? ... How can we figure out how many building blocks there are altogether?
105	John	Count!
106	Lily	Count!
107	KT	Shall we count? ... But we have already counted. How do we have to count <u>now</u>?

Figure 3. *The KT's facial expression and body positioning in the time of line 101*

In line 100 Fia says "We can count", which is a strategy to figure out how many building blocks there are altogether. In line 101 the KT, again, takes Fia's contribution, re-formulates it into a question and sends it back to the group. But this time she also gives a further clue. Figure 3 illustrates the KT's stance at the time of line 101, when she moves her hand away from the face, down in her lap, she straightens her back and makes an excited facial expression. In addition, she emphasises "count" with a marked rising intonation. I contend that by her bodily action, her facial expression and her rising intonation, the question is no longer only an appreciation and a further challenge, it is also a clue. It communicates that the children are on a mathematically interesting (and correct) path. It is the sudden change in the KT's facial expression and body positioning, from a "questioning look" in line 92–99, into excitement that gives the hint. However, the children (at least not all of them) do not seem to get the hint, because John continues to suggest *how many* building blocks there are (line 103).

When John suggests that there are twenty-six building blocks the KT changes her facial expression back to a "questioning look" and she responds; "Is it twenty-six? ((Pause)) How can we figure out how many building blocks there are altogether?" (line 104). John and Lily immediately respond "Count!", which indicates that they realise that it is not the answer that the KT is aiming for. The KT still has the same "questioning look" when she responds "Shall we count? ((Pause)) But we have already counted. How do we have to count now?" (line 107). To count is the basic strategy to solve the problem, however there are diverse ways to count in order to solve the addition problem. In the introduction the children, together with the KT, counted how many building blocks there were in each of the towers. By asking "How do we have to count now?" the KT communicates that there are other ways to count and that she wants the children to consider different strategies to solve the problem.

After the "How do we have to count now?" question, three other girls (Lily, Mia and Leah) contribute with ideas. (I do not present extracts from the transcripts of these three contributions due to space limitations).

I now move on to the interplay between the KT and Ada, which follows after Leah's explanation (to put all three towers on top of each other and then count all building blocks together):

126	Ada	((Holds her hand in the air))
127	KT	Yes
128	Ada	I know ... ehm ... if we say ... ehm ... ((Moves her body up and down)) do <u>not</u> count eight and then we just count further
129	KT	((Excited facial expression)) Oh, did you hear what she suggested? ((Whispers)) Would you like to show us?

Ada explains her idea in line 128, and the KT immediately reacts positively to Ada's contribution and turns to the other children (line 129). I interpret the KT's excited reaction as indicating that she recognises a quite sophisticated counting strategy for solving the addition problem, which she wants to share with the rest of the children. The KT's excited reaction, then, is not only intended for Ada, but for all children.

Figure 4. *The KT's facial expression and body positioning when she whispers "Oh, did you hear what she suggested?" in line 129*

Figure 4 illustrates the KT's facial expression and body positioning at the time of line 129. The KT uses her tone of voice (whispering), her facial expression (eyes and mouth open) and her index finger to indicate her positive evaluation of the suggestion. I argue that through these actions the KT communicates that this is an interesting suggestion that it is worth listening to. She highlights the suggestion to get the other children's attention. The other children are quiet, and their attention is on the KT (and Ada). The KT does not only indicate that it is important that the other children listen to the strategy, but she also communicates that *she* thinks it is an interesting idea. Her sudden positive reaction is not only,

I hold, (consciously) intended for the other children, it is also a genuine emotional action which is connected to her aim of the activity (to teach the children about counting strategies for addition). Considering the KT's profession as a pedagogue and her aim of the activity, Ada's contribution is probably interesting because she gets the opportunity to share a quite sophisticated strategy with the whole group. In addition, she gets the opportunity to learn more about Ada's reasoning.

This KT's positive response results in a positive emotional valuation from Ada, she smiles and blushes, and it seems to make her proud. Her contribution has been shared and evaluated as interesting. This encourages Ada to continue her explanation, and to continue to contribute in the ongoing discourse.

130	Ada	((Starts to count the yellow tower)) One, two, three, four, five, count without eight
131	KT	OK. Now you counted one, two, three, four, five and then, what do you want to do next? ((She uses her index finger to count the five building blocks in the yellow tower and then she moves her finger to the blue tower when she says "and then"))

In line 129, the KT asks Ada "Would you like to show us?", and Ada moves over to the building blocks and starts explaining her idea (line 130). She skips counting the eight building blocks in the red tower and starts counting from one on the yellow tower of five building blocks. Then she moves back to her place and verbally explains how to continue by saying "count without eight" (line 130). Her explanation is partly done with use of the building blocks and partly verbally.

Figure 5 illustrates the KT's, Ada's and Leah's stance at the time of line 131 when the KT moves her index finger from the yellow tower to the blue tower and says "... and then ...". The KT repeats Ada's actions (counts the five building blocks in the yellow tower), which helps Ada to focus

Figure 5. *The KT's (left), Ada's (right) and Leah's (middle) stance when the KT says "… and then …" in line 131*

attention to her previous actions. Then the KT moves her index finger to the blue tower when she says "... and then ...", which I interpret as a hint for a possible next move, namely to count further on the blue tower. In addition, the KT asks "what do you want to do next?" which is a request for Ada to explain further.

132	Ada	Ehm ... To count similar as we counted the yellow
133	KT	((Questioning look and pause)) Start to count from one at the bottom here? ((Points on the building block at the bottom of the blue tower))
134	Ada	Mm ((Agreement))
135	KT	One, two, three, four, five, six, seven, and then?
136	Ada	Ehm, we can just count like this all the time, without eight
137	KT	((Questioning look)) I think you have to show me, because I don't really understand what you mean. Maybe you can show [ ]
138	Ada	We count this one first ((Points at the yellow tower)) and then this one ((Points on the blue tower))
139	KT	Yes, maybe you can count it? Do as how you think, Ada
140	Ada	One, two, three, four five ((Counts the yellow tower)), six, seven, eight, nine, ten, eleven, twelve ((Continues to count the blue tower)). And then we just find it without counting
141	KT	Oh, we have to continue? ((Excited facial expression))
142	Ada	Mm ((agreement))

Ada does not act in correspondence to the KT's hint in line 131, instead she answers "Ehm ... To count similar as we counted the yellow" (line 132). Ada's response seems to confuse the KT, because she gives a questioning look again and, after a couple of seconds, she asks Ada "Start to count from one at the bottom here?" (line 133). The pause may indicate that the KT considers Ada's suggestion before she responds to Ada. I interpret the KT's question as a request for confirmation, if she has understood Ada's suggestion correctly, and Ada confirms the KT has understood her correctly (line 134). Then the KT does exactly as Ada suggests, she counts from one at the bottom of the blue tower, before she asks, "and then?" (line 135). The KT does not suggest any further actions, rather she asks Ada what to do next. In line 136 Ada says "Ehm, we can just count like this all the time, without eight" (line 136), which is very similar to her explanation in line 130. The KT seems unsure what to do and expresses this verbally and non-verbally in line 137 through her questioning look and through her utterance "I don't really understand what you mean". To promote Ada to change her explanation, the KT invites her to come forth and use the building blocks in her explanation by asking "maybe you can show [ ]?" (line 137). Ada comes forth and carefully explains her idea, both

verbally and by using the building blocks (line 140). Even though Ada is not able to fully complete her strategy (counting on from eight), she is able to count further from the yellow tower to the blue tower, and the KT is again able to understand Ada's counting strategy which she expresses in line 141 "Oh, we have to continue?", and Ada confirms that the KT has understood her correctly.

After this the KT and Ada together complete Ada's counting strategy (counting on from eight). And in the end of the segment the KT repeats Leah's and Ada's strategies with support from the other children.

Discussion

In the result section I identified the KT's actions which seemed significant for children's engagement in the discourse. I will now return to the research questions which aim to 1) characterise the KT's multimodal participation in the teaching-learning activity involving addition and counting and 2) illustrate how the KT's multimodal participation supports discourse and children's opportunities for learning. With respect to the first research question, I posit that three main characteristics of the KT's multimodal participation are significant: a) it changes from moment to moment in relation to children's contributions, b) is oriented towards the aim of the activity, and c) informsg the KT's underlying stance toward the children and their learning. In discussing these three characteristics I also point to the significance of the KT's multimodal participation for supporting discourse and children's opportunities for learning, which is the aim of the second research question.

How the KT often re-voices and reformulates children's suggestions (cf. O'Connor & Michaels, 1996) shows how the KT's contributions relate to children's contributions. For example, when Lily says "Twenty-one" (line 98) the KT responds "Is it twenty-one?" (line 99), and similarly when John says, "It is twenty-six" (line 103) the KT responds "Is it twenty-six?" (line 104). Both children's contributions are suggestions for the solution of the problem, but they are not what the KT is aiming for. The KT therefore reformulates children's suggestions into questions and sends them back to the group, which also illustrates how the KT's responses are oriented toward the aim of the activity. In these interactions the KT keeps a questioning look and a "neutral" tone of voice, which I interpret as indicating that she wants the children to continue to consider the problem. Another example that illustrates how KT's responses are related to children's contributions and simultaneously oriented toward the aim of the activity is when Fia says "We can count" (line 100), which is a strategy for solving the problem. The KT immediately responds "Maybe

we can count?" (line 101). The KT re-voices Fia's suggestion and reformulates it into a question, however this time she also clearly changes her body position, her facial expression and tone of voice. Her excitement indicates that the children are aligned with her aim for the activity.

I found that all the KT's responses are related to the children's previous contributions. Even when the KT responds "Yes" in line 127 it fundamentally relates to Ada's gesture in line 126 (Ada holds her hand in the air). This result is in fact not surprising, because it is incorporated in Vygotsky's (1987) dialectic perspective. The KT's answer relates to Ada's gesture, and similarly, Ada's hand gesture relates to the KT's utterance. It is the KT's response that informs the meaning of Ada's gesture in retrospect. Furthermore, how the KT's multimodal participation orients the activity (and thus the children's further actions) towards the aim of the activity, relates to a fundamental idea in activity theory: actions are initiated by the motive of the activity. It is the motive (the KT's aim of the activity) that initiates the KT's (and children's) actions. In this case it is illustrated by the way that the KT's emotional actions alternate between excitement, curiosity and uncertainty. Roth and Radford (2011) show how a child's emotions can orient activity towards the object of the activity, which is similar to the results in this study. My analytical findings, however, indicate that the KT's emotional actions are part of the orientation of the activity. Whenever the children are on their way toward a counting strategy for addition, the KT's participation changes from a questioning look into excitement (and vice versa). The KT's emotional actions indicate how children's contributions relate to the aim of the activity; i.e. whether the children are moving in the "desired direction" or not.

In addition, the KT's multimodal participation has some characteristics which may indicate her underlying "stance" toward the children and their learning. Firstly, the KT uses a wide range of questions. Twenty-one out of thirty KT utterances in the class-time reported on above were questions. The other nine utterances were utterances like "Lily", "Leo" (naming the children), "Yes" etc. The KT never asked closed, factual or procedural questions, which invite predetermined answers, (cf. Myhill & Duncan, 2005). The types of questions that the KT chose to use, invited the children to explain and reflect and thus the discourse can be considered as exploratory (cf. Mercer, 2000) or as inquiry (cf. Roth, 1996; Wells, 1999). Furthermore, the KT kept this particular segment of activity moving for approximately five minutes through the use of open questions. The children were given ample opportunities to contribute to the conversation, which we know is difficult in teacher led activities and important for children's learning (cf. O'Connor & Michaels, 1996;

Dovigo, 2016). Secondly, the KT never (explicitly) evaluated the children's contributions, that is she never said whether the suggestions were correct or incorrect, in contrast to IRE-exchanges (cf. Wood, 1992). By re-voicing children's suggestions, the KT appreciated almost every child contribution, even when the suggested solution was not what the KT aimed for. At the same time, she re-formulated the suggestions into questions and sent them back to the group. The KT followed up children's contributions and promoted them to continue to consider the problem, which is similar to the IRF-exchange described by for example Wells (1999) or Rojas-Drummond and Mercer (2003).

My study shows that learning activities in kindergarten may be accomplished with an "open conversation" where children are given ample opportunities to participate with, and argue for, their ideas. Although I note above that the KT did not explicitly evaluate children's contributions as correct or not, I argue that she implicitly did by her multimodal participation. The KT's questioning look or excitement oriented the children toward the aim of the activity, which can be considered as a type of evaluation because these implicitly informed the children if they were moving in the desired direction or not.

A third and important characteristics which indicates the KT's underlying stance toward the children and their learning is how she used the building blocks in the activity. Through the whole segment, the KT kept the three towers of building blocks close to her. The children did not have direct access to the building blocks, they only got access when the KT allowed them to come forward. Because the children did not have direct access to the building blocks, they needed to verbally explain, and direct what actions they wanted the KT to perform on the building blocks. By limiting the children's access to the building blocks, she "forced" them to use other semiotic means (like language and gestures) to communicate their ideas. By "force" I mean that she limited the children's agency, so they would go along a specific route or sequence of actions. Thus she "forced" the children to move toward a more abstract form of reasoning. However, sometimes she gave the children access to the building blocks, and perhaps she did that because she realised that the children needed the building blocks to reason and explain their ideas. Carpenter and Moser (1982) argue that children can be encouraged to use the "counting-on" procedure if there are no physical artefacts available for the children to manipulate. In this segment Ada suggested to use the "counting-on" procedure to solve the problem, and perhaps she was promoted to use this strategy because the building blocks were not initially available for her to manipulate.

Roth and Radford (2011) argue that the most important aspect to understand a teaching-learning activity is to identify the underlying grounds that make the situation happen. They argue that words (and other semiotic means) belong to systems of ideas and are carriers of ideologies, and thus reflect "the social, political, and theoretical position of the person uttering it" (Roth & Radford, 2011, p. 104). Therefore, it is important to investigate the underlying "tone" of the words, and to display the ideologies behind. In this segment, the KT's use of questions and non-evaluative verbal response to the children may indicate the KT's underlying stance toward the children and their learning. The KT's use of building blocks may be a result of the written activity description which prepares for a whole-group session with only three towers. However, the activity description says nothing about *how* the KT should use the building block, and thus her use can still be argued to be part of the KT's underlying position. Her sensitive way of using the building block is most likely influenced by her underlying stance toward the children and their learning and is revealed through her multimodal participation.

My final discussion point concerns Radford's (2008, 2013) claim that learning is more than becoming aware of cultural ways of thinking and acting, it is also about becoming in the process of subjectification, which is a "processes of creation of a particular (and unique) self" (Radford, 2013, p. 27). I hold that the KT's dynamic multimodal participation also illuminates the KT's way of becoming in the activity. The KT's actions (verbal and non-verbal) are always balanced between her earlier experiences, which in this case is mediated by her underlying stance, children's contributions and the aim of the activity. The tensions that are created between the past, present and future is what constitutes the KT's moment to moment acting. Who the KT was when she entered the activity is transformed in the encounter with the children. This process is particularly salient in the part of the segment where the KT expresses that she does not understand. The KT is positioning herself within the unfolding activity, trying to understand the children. The KT shows a genuine interest in understanding the children which puts her in a position where she must be led by the children (as she is led by Ada). Vygotsky (1989) said that "we become ourselves through others" (p. 56, in Roth & Radford, 2011, p. 87). The way that the KT continuously transforms her unique participation in the moment in relation to children's contributions, and how she positions herself within the unfolding activity, trying to understand the children, illustrates how she becomes her unique self in the encounter with the children.

The consequences of these observations for practice is that KTs, and teachers in school, can benefit from being consciously aware of the

affect their bodily actions have on children's mathematical reasoning, and how they can engage children in mathematical discourse without having to "teach" (i.e., tell) children mathematical concepts and relations. This study shows how mathematics emerges from the participants joint activity, that is through KT's multimodal engagement with the children. Moreover, in school mathematical activities are usually more structured than what children are used to in kindergarten and there is an increasing emphasis on expressing mathematical ideas verbally and symbolically. This study illustrates how KTs can prepare for a smooth transition from kindergarten to school by carefully introducing children to mathematical thinking through semi-structured activities.

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References

Baroody, A. J. & Purpura, D. J. (2017). Early number and operations: whole numbers. In J. Cai (Ed.), *Compendium for research in mathematics education* (pp. 308–354). Reston: NCTM.

Carlsen, M. (2013). Engaging with mathematics in the kindergarten. Orchestrating a fairy tale through questioning and use of tools. *European Early Childhood Education Research Journal*, 21 (4), 502–513.

Carpenter, T. P., Moser, J. & Romberg, T. (1982). *Addition and subtraction: a cognitive perspective*. Hillsdale: Lawrence Erlbaum.

Dovigo, F. (2016). Argumentation in preschool: a common ground for collaborative learning in early childhood. *European Early Childhood Education Research Journal*, 24 (6), 818–840.

Erfjord, I., Hundeland, P. S. & Carlsen, M. (2012). Kindergarten teachers' accounts of their developing mathematical practice. *ZDM*, 44 (5), 653–664.

Fuson, K. C. (1992). Relationships between counting and cardinality from age 2 to age 8. In J. Bideaud, C. Meljac & J. P. Fisher (Eds.), *Pathways to number, children's developing numerical abilities* (pp. 283–306). Hillsdale: Lawrence Erlbaum.

Gee, J. P. (2008). *Social linguistics and literacies: ideology in discourses* (3rd edition). London: Routledge.

Gee, J. P. (2011). *An introduction to discourse analysis: theory and method* (3rd edition). London: Routledge.

Kirby, P. (1996). Teacher questions during story-book readings: Who's building whose building? *Reading*, 30 (1), 8–15.

Lillejord, S., Borte, K., Halvorsrud, K., Ruud, E. & Freyr, T. (2017). *Transition from kindergarten to school: a systematic review*. Oslo: Knowledge Center for Education.

Mercer, N. (2000). *Words and minds: how we use language to think together*. London: Routledge.

Myhill, D. & Dunkin, F. (2005). Questioning learning. *Language and Education*, 19 (5), 415–427.

O'Connor, M. C. & Michaels, S. (1996). Shifting participant frameworks: orchestrating thinking practices in group discussion. In D. Hicks (Ed.), *Discourse, learning and schooling* (pp. 63–103). New York: Cambridge University Press.

Radford, L. (2008). The ethics of being and knowing: towards a cultural theory of learning. In L. Radford, G. Schubring & F. Seeger (Eds.), *Semiotics in mathematics education: epistemology, history, classroom, and culture* (pp. 215–234). Rotterdam: Sense Publishers.

Radford, L. (2009). Why do gestures matter? Sensuous cognition and the palpability of mathematical meanings. *Educational Studies in Mathematics*, 70 (2), 111–126.

Radford, L. (2013). Three key concepts of the theory of objectification: knowledge, knowing, and learning. *Journal of Research in Mathematics Education*, 2 (1), 7–44.

Radford, L., Edwards, L. & Arzarello, F. (2009). Introduction: beyond words. *Educational Studies in Mathematics*, 70 (2), 91–95.

Rojas-Drummond, S. & Mercer, N. (2003). Scaffolding the development of effective collaboration and learning. *International Journal of Educational Research*, 39 (1), 99–111.

Roth, W.-M., (1996). Teacher questioning in an open-inquiry learning environment: interactions of context, content and student responses. *Journal of Research in Science Teaching*, 33 (7), 709–736.

Roth, W.-M. (2001). Gestures: their role in teaching and learning. *Review of Educational Research*, 71 (3), 365–392.

Roth, W.-M. & Radford, L. (2011). *A cultural-historical perspective on mathematics teaching and learning*. Rotterdam: Sense.
Vygotsky, L. S. (1987). Thinking and speech. In R. W. Rieber & A. S. Carton (Eds.), *The collected works of L. S. Vygotsky* (pp. 37–285). New York: Plenum Press.
Wells, G. (1999). *Dialogic inquiry: towards a socio-cultural practice and theory of education*. Cambridge University Press.
Wood, D. (1992). Teaching talk. In K. Norman (Ed.), *Thinking voices: the work of the national oracy project* (pp. 203–214). London: Hodder & Stoughton

Notes

1 The term "discourse" will be defined in the next section.

2 Transcription codes: (( )) denotes non-verbal actions or contains explanations and interpretations necessary to understand the dialogue; _ denotes that the underlined word is emphasised; ... denotes a pause in the verbal utterance; [ ] denotes that the utterance is cut off by another participant.

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