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Kindergarten teachers' orchestration of mathematical learning activities: the balance between freedom and structure

Svanhild Breive¹

¹University of Agder, Norway; svanhild.breive@uia.no

This paper reports on a multiple-case study which focuses on four kindergarten teachers' orchestration of mathematical learning activities with respect to the degree of freedom, and what impact their orchestration has for children's mathematical learning possibilities. The study draws on Valsiner's (1987) zone theory to investigate the relationship between zone of free movement (ZFM) and zone of promoted action (ZPA) which the kindergarten teachers set up to canalise children's actions and thinking and thus development. The results show that in the kindergarten where the ZFM is gently set up and limited to mathematics, and where the kindergarten teacher sensitively sets up the ZPA and promotes children to share, argue for and explain their mathematical ideas, and explicitly promotes the children to collaborate, is where most problem-solving interaction occur and thus facilitate children's learning possibilities the most.

Keywords: Kindergarten, mathematics, orchestration, zone of free movement, zone of promoted action.

Introduction

This paper reports on a multiple-case study which aims to investigate four kindergarten teachers' (KTs') orchestration of pre-designed mathematical learning activities and what impact their orchestration has for children's learning possibilities. The current debate about mathematics in kindergarten is seldom about whether or not mathematics should be part of the curricula in kindergarten, rather on how mathematical activities in kindergarten should be orchestrated¹ (Gasteiger, 2012; Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009; van Oers, 2010). Children's opportunities to take part in mathematical discourses are important in learning mathematics, but in activities where the kindergarten teacher has a pedagogical aim, it may be difficult to balance teacher-talk and child-talk (Dovigo, 2016). The study reported here focuses on four KT's orchestration of mathematical learning activities with respect to the degree of freedom² and aims to:

- Investigate the characteristics of four kindergarten teachers' orchestration of pre-designed mathematical activities with respect to the degree of freedom, and;
- Investigate what impact the four kindergarten teachers' orchestration of the mathematical activities has for children's mathematical learning possibilities.

¹ The term 'orchestration' is used in accordance with Kennewell (2001), as a broad metaphor for how the KT's structure or organise the activity through use of questions, cues, prompts, information, demonstrations etc.

² The term 'degree of freedom' is used in accordance with van Oers (2014) as a characteristic of the way an activity (in cultural-historical activity theory) is carried out and refers to the "degrees of freedom allowed to the actor in the choice of goals, tools, or rules" (p. 113, emphasis in origin), which in turn initiates the actor's choices of actions.

Theoretical framework

The study reported here draws on Valsiner's (1987) zone theory to investigate the relationship between freedom and structure in four KT's orchestration of mathematical learning activities. The balance between freedom and structure is the main focus when Hirsh-Pasek et al. (2009) and Weisberg, Kittredge, Hirsh-Pasek, Golinkoff, and Klahr (2015) discuss 'playful learning' as an educational approach in kindergarten. Playful learning captures both 'free play' where children play without interference from adults, and 'guided play' where the KT organises the learning environment and guides the play in desired directions with respect to a learning aim. Weisberg et al. (2015) argues that, although the KT's initiate and guide the activity in guided play, the KT's must make room for children's self-directed exploration, and it is this balance between freedom and structure that makes guided play such an effective teaching tool. Similar van Oers (2014) argues that playful learning activities should contain some elements of instruction. "The nature of the actions embedded in play can vary with respect to their degree of freedom allowed, as long as the activity as a whole remains a playful activity" (van Oers, 2014, p. 121). The learning activity must be engaging and give possibilities for the players freedom to explore the (mathematical) objects in their own manner.

In his study on preschool children's argumentation, Dovigo (2016) investigates children's learning opportunities in different types of conversations (peer-talk and child-teacher talk). Dovigo found that children had richer opportunities to participate and asked more questions in peer-talk than in child-teacher talk. It was a clear tendency that in child-teacher talk, the KT talked more than the children. However, the children's abilities to build arguments were limited in peer-talk and were facilitated in child-teacher talk. The KT's facilitated children's explanations and helped them to elaborate their argumentations, which again improved children's critical thinking and abilities to collaborate.

Through his zone-theory, Valsiner (1987) explores the development of children's actions and thinking through organisation of person-environment relationships. The physical environment of the child is the cultural frame which the child is acting within and thus develop its thinking. Valsiner's theory emphasises that both the developing child and the environment are structurally organised, however the structuring nature of the child and the environment is continuously and dynamically transformed. Valsiner (1987) uses three zone concepts to conceptualise the dynamic environmental structures that organise the child's development: Zone of Free Movement (ZFM); Zone of Promoted Action (ZPA); and Zone of Proximal Development (ZPD). The ZFM is co-constructed by the child and the adult and organises the "child's (1) access to different areas in the environment, (2) availability of different objects within an accessible area, and (3) ways of acting with available objects in the accessible area" (p. 97). Within the ZPA there may be activities or objects which the child is promoted to engage with. An important characteristic of the ZPA is its non-binding nature: The child does not need to follow the ZPA and can act with other objects (in other ways) within the ZFM. The child cannot be 'forced' to accept the ZPA unless the ZPA is turned into ZFM. The ZFM and ZPA must be considered as a unit and Valsiner (1987) labels it the 'ZFM/ZPA complex'. The ZFM/ZPA-complex work as a mechanism to canalise the child's actions and thinking and thus development in culturally accepted ways. In addition, Valsiner (1987) discusses how ZPD relates to

the ZFM/ZPA-complex, but due to space limitations, this study focuses primarily on the relationship between ZFM and ZPA in four kindergartens with respect to mathematics.

Methodology

The study reported here is a multiple-case study (Yin, 2014), which aims to characterise four KT's orchestration of pre-designed mathematical activities and its impact for children's mathematical learning possibilities. It is part of a larger study on mathematical teaching and learning in kindergarten and situated within a Norwegian research and development project called the Agder Project³ (AP). The intervention of the AP was based on mathematical activities which were pre-designed in collaboration between researchers (including myself) and the KTs in the focus groups of AP. The mathematical activities suggest how to organise learning sessions, what materials to use and suitable questions to ask etc. in order to promote a playful and inquiry-based approach to the teaching and learning of mathematics. The activities were meant as suggestions not as scripts which the KTs needed to follow to the letter and this was communicated both verbally and in written form to the KTs before the intervention. The activities are described in Størksen et al. (2018), a book containing one-page outlines of the activities. This study takes a qualitative approach to data collection and data analysis and the empirical material was collected over two observation periods (autumn 2016 and spring 2017) during the intervention of the AP. Observations were conducted of approximately 40 minutes sessions where the four KTs, who were part of the focus groups of the project, implemented the pre-designed activities. Interviews were conducted in each kindergarten after each observation period. Overview over data sets (observations and interviews) in each kindergarten is illustrated in Table 1 below. All four KTs have at least 15-years working experience.

	KT1	KT2	KT3	KT4
Autumn 2016	5 obs. + 1 interv.	4 obs. + 1 interv.	5 obs. + 1 interv.	3 obs. + 1 interv.
Spring 2017	6 obs. + 1 interv.	7 obs. + 1 interv.	0 obs. + 0 interv.	4 obs. + 1 interv.

Table 1: Overview over data sets (observations and interviews) in the four kindergartens

The empirical material was collected through ethnographic field notes (Emerson, Fretz, & Shaw, 2011) from observations and interviews. Field notes were written during and/or straight after each observed session and were supplemented when having conversations with the KTs after each session. Field notes from the interviews were made straight after the interviews and were extended when the video-recordings of the interviews later were watched. Field notes should not, ideally, include interpretations of the observed interaction (Emerson et al., 2011). However, as Emerson et al. (2011) argues, when the fieldworker starts to work with the field notes, he/she orders patterns of interactions and decides what to include and leave out from the field notes. In this research study

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the research questions were made before conducting the field work, which guided what I was especially looking for and thus what I included and left out from the field notes. The field notes must therefore, to a certain extent, be regarded as interpretative or analytical.

Processing and analysing data went through an iterative process. Instead of using the field notes as 'raw material' from which I started a coding process, I worked directly with the field notes and carefully contracted them into profiles of the KT's orchestration and their interaction with the children. Since the field notes were already to some extent analytical, they served as a useful starting point for this purpose. The profiles concern four key points: (1) Children's access to different areas in the environment; (2) children's freedom to act (physically) within the accessible area; (3) children's freedom to contribute with questions, mathematical ideas and argumentations etc.; and (4) the degree to which problem-solving interaction was promoted (that is the degree to which the children were promoted to ask questions and explain and argue for their ideas to solve mathematical problems). Key points 1-3 concern the KT's orchestration of the mathematical activities with respect to the degree of freedom and intends the ZFM. Since the ZFM is co-constructed by the child and the adult, children's eagerness to participate and take initiative are also used to identify ZFM. Key point 4 concerns how the KT's promote children to ask questions, explain and argue for mathematical ideas to solve mathematical problems, which intends the ZPA. As Valsiner (1987) argues, ZFM and ZPA are related and work as a unit to canalise children's development, and in this case, learning and development related to mathematics. In this study I identify learning possibilities whenever the KT's and the children together solve mathematical problems through questions, explanations and argumentations.

The profiles, which will be presented below, are of course tendencies not absolute characteristics. The KT's orchestration with respect to the degree of freedom changes dynamically during each session and from session to session. In addition, the profiles are relative, which means that the degree of freedom in one kindergarten is relative to the three other kindergartens and cannot provide an indication for how it relates to other KT's orchestration in other contexts.

Profiles of four kindergarten teachers' orchestrations

Kindergarten teacher 1

KT1 orchestrated the mathematical activities with a relatively high degree of freedom, which is based on the way that the children were allowed to move around in the room (and even walk out of the room) and to talk about almost whatever they wanted, like birthday parties or their parents' occupation etc. The KT never told the children to sit down and pay attention, instead she promoted the children to do so by the way she enthusiastically presented the activities, which captured the children's attention. For example, in an activity about reflection symmetry, the KT introduced the activity having diverse reflection symmetrical objects in a plastic bag without telling what was inside. She shook the bag and whispered, "Listen!", which made the children curious and created joint attention. Another characteristic of the KT's orchestration was that the KT listened to almost every child's contribution (not only related to mathematics). In one of the conversations with the KT, she expressed that her desire to listen to and appreciate every child's contribution could be a hinderance for her, because her attention became very shifty. She rapidly turned her attention from

one child to another. The children eagerly participated in the activities, however, as mentioned above, they often contributed with other ideas than mathematics. The KT expressed that she had a challenging group of children but their ability to pay attention to mathematics grew during the intervention. There were a lot of 'golden moments' for problem-solving interaction. The KT and the children initiated a lot of interesting 'topics' for investigation, but very few ideas were thoroughly discussed. Mathematical questions were often (not always) considered briefly, and the children seldom had to ponder about problems and to express mathematical ideas, argue for and explain their ideas in order to solve the problem. Because the KT gave the children a lot of freedom to talk and payed attention to almost every contribution, the conversations moved very quickly from one topic to another.

Kindergarten teacher 2

KT2 gave the children a relatively high degree of freedom to talk, however she often restricted children's talk to mathematics by ignoring some of the contributions that were about the children's everyday experiences. The KT also restricted the children's freedom to act (physically) to areas or with objects relevant to the mathematical activity. Although the KT for the most part focused attention to mathematics, she gave the children freedom to suggest other mathematical issues than what she initially introduced. Similar as KT1, the KT2 presented the activities in an exciting way, by use of for example excited face expressions and whispering, which captured the children's attention and promoted the children to contribute. But sometimes she also asked questions directly to children to capture their attention. For example, when Carl was distracted by something else, she said: "Carl, do you know how many building blocks there are in the red tower?" When Carl said that he didn't know, the KT further asked "Would you like to help me count?" This helped Carl, who often had difficulties paying attention, to focus his attention on mathematics. The conversations between the KT and the children were almost always mathematical, and sometimes the KT and the children had longer conversations about mathematical problems. The children had to argue for and explain their ideas in order to solve the problems, and the children eagerly participated with mathematical ideas and explanations. In addition, the KT seemed to focus on collaboration. For example, the KT had a conversation with the children about the meaning of collaboration, and the KT promoted the children to help each other if needed. She also promoted the children to listen to each other by for example asking the group of children: "Did you hear what Ada suggested?".

Kindergarten teacher 3

KT3 was a football trainer in his spare time, which was somehow recognisable from his orchestration of the activities. He gave the children a relatively high degree of freedom to act (physically) and focused on 'doing' mathematics, which for him was when the children got opportunities to use their hands, their body and various artifacts to solve mathematical tasks. In one of the conversations with the KT he expressed that 'doing' mathematics was for him an important feature of mathematics in kindergarten and therefore he especially liked physical outdoor activities. In addition, he was giving short 'missions' for the children to perform. For example, in the 'Sorting Shoes' activity, when the children had to figure out how many shoes there were in each category,

the KT gave each child a 'mission' to draw equally many lines in the bottom of the diagram as there were shoes in each category. The KT expressed several times that it was important to give the children challenging but manageable tasks, so they felt they succeeded. He often encouraged the children, in an enthusiastic manner, with comments like "good" or "great" etc. It seemed that the children enjoyed the activities and the way that the KT encouraged them. The children eagerly participated and seemed to have fun. There was relatively little problem-solving interaction and the children often solved tasks without having to explain or argue for their ideas. For example, in the activity called 'Tripp, Trapp', where the children should count stairs in a staircase and find out what number each stair had, the KT made A4 papers with numbers from 1-24 on and the children, one by one, had to pick an A4 sheet and place it on the correct stair. (Stair number 15 should have the A4 sheet with the number 15 on). The children just performed the tasks, without having to explain what they did, and why they did what they did. Sometimes the KT promoted the children to reflect on their solution strategies in retrospect, however the children's explanations were seldom helping them to solve problems in the first place.

Kindergarten teacher 4

KT4 gave the children relatively little freedom to act (physically) or talk which is based on the way that she, to a large degree, controlled who was going to talk (or 'do' something) and when. For example, in an activity called 'The Farm' the children were, at one point in the activity, supposed to find how many animals there were on the farm. First the KT asked a girl, "Helene, can you figure out how many animals there are all together?". After Helene had counted and answered the KT asked a boy, "John, can you find how many different animals there are?". The KT continued to give similar 'missions' to each child. The KT made sure that each child got the opportunity to answer or 'do' something mathematically, and she appreciated children's contributions by comments like 'that's correct', 'very good' etc. The KT expressed in one of the conversations that it was important that the children learnt to respect the other children and to wait for their turn in an activity. The KT also expressed that some activities were difficult to implement as outdoor activities, because the children often got disturbed by other things. These characteristics are of course tendencies, and sometimes the activities were a lot more open where the children had a lot more freedom to act. But, as she also expressed in one of the interviews, she thought it was difficult to 'hold back' and give room for the children to figure out the problems themselves without too much interference. It is difficult to state how 'eager' the children were to participate, because they seldom answered or did something without being asked. They accepted the KT's request to sit and wait for their turn. In some activities, like when they measured how much water there was room for in a tank, the children laughed and were having fun and showed eagerness to participate. Still they were asked to wait for their turn and respect that each child got the same opportunity to fill water. There were few incidents where the children together solved problems by expressing ideas and arguing for solutions. The children were waiting for their turn to answer or to perform 'missions'. The KT sometimes asked the children to explain what they did when they solved a task, but this explanation did not help the children to solve the problem, but to reflect on their strategy in retrospect.

Discussion

From the results above, it seems that KT1 is very concerned about freedom, and the ZFM is relatively wide compared with the ZFM the other KT's set up, both with respect to what the children are allowed to talk about and what they are allowed to do (physically). The children are even allowed to walk out of the room if they want to, and they can talk about whatever they want. KT2 restricts the ZFM to mathematics, both what the children can physically do and what the children are allowed to talk about. However, KT2 gives the children freedom to talk about and work with other mathematical objects than what she initially promotes. KT3 restricts the mathematical talk to specific mathematical areas, however the ZFM is relatively wide when it comes to what the children are allowed to do (physically). The KT3 gives the children freedom to move physically and to make loud voices when they solve the mathematical tasks. KT4 is the most controlling of the four KT's, and the ZFM is relatively narrow both with respect to what the children are allowed to do (physically) and what the children are allowed to talk about. KT4 decides, to a large degree, who is allowed to talk (or 'do' something), when the children are allowed to talk (or 'do' something) and what the children are allowed to talk about.

Considering the ZPA, the results illustrate how the KT's promote children to ask questions, explain and argue for their ideas in order to solve mathematical problems. The children do not need to accept the ZPA set up by the KT, but instead of turning the ZPA into ZFM the KT may, I hold, 'advertise' for the ZPA to promote the child to act in a desired manner. In K1 the KT promotes children to act mathematically by acting in an exciting way, and by introducing the activities in a manner which makes the children curious. The children sometimes accept the ZPA, but sometimes they do not. The KT1 is carefully promoting the children to think mathematically, but the ZPA (related to mathematics) is never turned into ZFM. The KT2 also promotes children to think mathematically by acting in an exciting way. The ZPA is related to specific mathematical areas, however the ZFM is related to mathematics in general. Sometimes, especially related to some children, the KT2 carefully turns the ZPA into ZFM, that is the KT limits the ZFM to specific mathematical tasks whenever the children do not pay attention. In addition, the KT explicitly promotes the children to help each other and to collaborate which, I hold, is important for the way that the children solve problems together. KT3 promotes children to think mathematically or 'do' mathematics by a quite tight ZFM related to mathematics. The ZPA is often turned into ZFM by asking the children to perform 'missions'. However, the ZFM is relatively wide related to physical actions. KT4 almost always turns the ZPA into ZFM. What the KT promotes the children to do is also what the KT allows the children to do.

Considering the characteristics of ZFM/ZPA complex in each kindergarten which according to Valsiner (1987; 1997) canalise children's actions and thinking and thus development, it seems that the KT's who limit children's actions to mathematics, but where the children's freedom is relatively wide related to what the children may talk about within mathematics and who is allowed to speak, promotes most problem-solving situations (KT2), and thus children's opportunities for learning. How the ZFM/ZPA complex canalise children's development is not only related to the boundaries of the zones itself, but *how* the ZFM and ZPA are set up. The KT2 is relatively mild in her way of setting up the ZFM, and instead of turning the ZPA into ZFM she acts in an exciting way which promotes the children to accept the ZPA. The KT2 'advertise' for the ZPA by the way she presents

the mathematical problems and makes the children want to pay attention and accept the ZPA. The KT4 is not that enthusiastic, and perhaps that is why she must turn the ZPA into ZFM to make the children pay attention and to accept the ZPA. The KT1 is also enthusiastic in setting up the ZPA, but since the ZFM is relatively wide, the children often choose to act in other ways than what the KT promotes. The results support Hirsh-Pasek et al. (2009), Weisberg et al. (2015) and van Oers (2014) who emphasise that playful learning activities should have some structure as long as the activity as a whole remains a playful activity and as long as the KTs gives freedom for children's self-directed play, so they may explore the content in their own manner. The results also supports Dovigo's (2016) results in the sense that whenever the KT is structuring the environment around mathematics, but opens up for children's own exploration around mathematical ideas, the children are canalised into more problem-solving activity and thus create possibilities for children's mathematical learning.

The results indicate that instruction which structures children's actions around mathematics but introduces the mathematics in an 'exciting' way and allows and promotes children to contribute with various mathematical ideas not necessarily related to the aimed subject area, captures children's attention and promotes their voluntarily participation in the problem-solving activity and thus facilitates children's possibilities for mathematical learning.

Limitations of the study

This study focuses on the KTs' orchestration and its consequences for children's learning possibilities and does not consider how the children, in light of for example their background, influence the KTs' orchestrations and the nature of interaction in each kindergarten. Moreover, in this study the ZFM/ZPA complex is considered on a group level. It would be interesting to investigate the ZFM/ZPA related to each child in the groups, to see which children benefitted the most from the KTs' different orchestrations.

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