Positioning in mathematics: A case of 6-year-old students collaborating on combinatorics

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Abstract: In mathematics education, collaboration between students is often emphasised as something desirable. The focus of this paper is on positioning in mathematics during collaborative problem solving and problem posing while exploring combinatorics. The study utilises the Learning Design Sequence model for lesson design and positioning theory as an analytical framework. In a sequence of lessons, students worked with both problem solving and problem posing, using different ways of representing their solutions, such as pictures, physical objects, and digital animations. One case of two 6-year-old students is used to illustrate their positioning during this sequence of lessons. One conclusion is that, when collaborating, students' views of each other as learners in general and mathematics learners in particular may hinder the process of meaning making in mathematics.

Keywords: positioning, mathematics, collaboration, problem solving, digital technology

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1 Introduction

The empirical material in this study derives from an intervention in which 6-year-old Swedish students were introduced to problem solving and problem posing in mathematics. In mathematics education research in general, and specifically in studies on problem solving, collaboration between students is frequently emphasised as something desirable (e.g., Liljedahl, 2021). However, there are also studies indicating that collaboration when working on problem solving can be challenging for young students (see, for example, Palmér & van Bommel, 2015).

In the sequence of lessons used as an example in this paper, the mathematical task is a combinatorial task where the students are to consider in how many ways three toy bears in different colours can be arranged in a row on a sofa. To make the task meaningful for young students, it is presented as a conflict between the toy bears, where the bears cannot agree on who should sit where on the sofa. One toy bear then suggests that they could change places every day. The task for the students is to determine how many consecutive days the bears could sit on the sofa in different arrangements. Thus, it is an enumerative combinatorial task where the students are to count the permutations for n = 3. In the sequence of lessons, the students first work on the task together in pairs using paper and pen. Then they record their solutions in a digital animation and, finally, they are to pose a similar task to a peer. Thus, they work with both problem solving and problem posing, using different ways of representing their solutions such as pictures, physical objects, and digital animations. Students' solutions to this task have previously been studied by Palmér and van Bommel (e.g., 2018, 2020) as well as Ebbelind et al. (2023). However, the focus of this paper is not on the students' solutions per se but on their positioning when collaborating on the sequence of problem-solving and problem-posing tasks presented above. The specific question elaborated on is: Does students' positioning when they are collaborating influence their meaning making in mathematics, and if so, how?

2 Literature review

As mentioned, in a sequence of lessons, the students in this study first use paper and pen when working on problem solving. After that they record their solutions in a digital animation. Finally, they work on problem posing by posing a similar task to a peer.

The importance of young students becoming familiar and comfortable with problem solving and problem posing is pointed out by several researchers (see, for example, English, 2004; English & Sriraman, 2010). However, few studies focus on problem solving in early mathematics, and even fewer focus on problem posing (e.g., Cai et al., 2015; English & Sriraman, 2010). Yet, incorporating problem posing as part of problem solving has been shown to develop students' problem-posing as well as their problem-solving skills (e.g., Ellerton et al., 2015; Palmér & van Bommel, 2020). Also, some studies have shown the successful use of problem posing in early mathematics education (e.g., Palmér & van Bommel 2018, 2020).

In Sweden, the use of digital technology is included in the curricula for all grades. Studies of digital technology in mathematics education show varied results – positive, neutral, and negative (Baki et al., 2011). These different results can be linked to the digital tool used, the way it was used, and the purpose for which it was used. For example, simply adding an interactive whiteboard does not turn a classroom into an interactive teaching environment. On the contrary, an interactive whiteboard can lead to less interaction (Bourbour, 2015; Higgins et al., 2007). Open, challenging, and exploratory questions have proven to be successful in connection with the use of digital technology in early mathematics education (Sarama & Clements, 2009). Further, studies indicate that when both analogue and digital resources are used, these often add value to each other (Maschietto & Soury-Lavergne, 2013).

3 Learning Design Sequence and positioning theory

In the study, the Learning Design Sequence (LDS) model is used as a basis for the design of the lessons, and positioning theory is used as an analytical tool.

3.1 Learning Design Sequence

In the study, the LDS model (e.g. Björklund Boistrup & Selander, 2022; Selander, 2021) was used as a tool for planning the lessons where the students would work with problem solving and problem posing. One important premise in this theory is the multimodal perspective, which assumes that, in interaction, multiple modes are used. From this perspective, teachers' choices in teaching are seen as design *for* learning, while students' choices are described in terms of design *in* learning. The teacher's design for learning includes choices concerning activities, learning tools, and other resources provided for the students. The students, as designers in learning, make choices on how to take part in the activities as well as what resources to use and how.

The LDS model comprises three main parts: i) framing and setting, ii) primary transformation unit, and iii) secondary transformation unit. A teacher's overall design for learning relates to, for example, curriculum documents and various institutional norms and regulations. The teacher also has a purpose for the planned activities, in our case to have the young students explore combinatorics through problem solving and problem posing. During the primary transformation unit, students participate in various activities, use available resources, and transform the content by reading, listening, acting, speaking, drawing, writing, etc. The primary transformation unit may lead to students creating some form of representation to communicate their ideas about the content. During the secondary transformation unit, the students' representation and activities during the primary transformation unit may be the focus of meta reflective conversations between the teacher and students.

Furthermore, in this model, the teacher's choices (e.g., of activities) position students in various ways (e.g., capable of taking responsibility for their learning)

Similarly, students position themselves, the teacher, and each other in different ways through their choices.

3.2 Positioning theory

According to positioning theory, the roles people adopt in social relationships, such as classroom discourses, are not fixed but emerge in interaction. Further, systems of meaning "regulate rather than cause human behavior, with the implication that individuals have some choice as to which rules and norms they follow in relation to the projects they have in hand and what they take the social and physical environment to be" (Harré & Moghaddam, 2014, p.129). Positioning involves either individuals situating themselves or being situated by others in diverse situations. As such, positioning is a dynamic process influenced by factors such as familiarity with a situation, experience level, or perceived status. In essence, how a person positions themselves or is positioned evolves and varies based on specific situations or contexts, sometimes occurring almost simultaneously (Davies & Harré, 1999).

The positioning theory includes a three-part framework of storylines, speech acts, and positions. Storylines are narrative conventions that emerge as people interact. In a mathematics classroom, the storyline is about the positions being created but also about the learning and the mathematics content itself. Speech acts are significant actions, movements, and all kinds of communication that comprise the interaction. As such, speech acts build and reproduce storylines that invoke rights and duties, that is, positions (Harré et al., 2009). There are three ways to position oneself in interactions: willingness (the extent to which someone is prepared to position others and themselves), capability (the extent to which someone can take the position offered), and power (the extent to which someone is permitted, allowed, or encouraged to take the positions).

4 The study

This qualitative case study was conducted with 45 students from two Swedish preschool classes (6-year-olds). In Sweden, 6-year-old students are enrolled in preschool class, which is an obligatory year of schooling in the transition between preschool and compulsory school. The teachers in these classes have, for several years, been collaborating with two of the researchers in this study. Due to this collaboration, they are well acquainted with the combinatorial task, since they have conducted it previously with other groups of students. However, the part of the task where students create digital animations was new to the teachers.

Following Swedish ethical research guidelines, parents gave written consent for their children's participation in the study (Swedish Research Council, 2017). To ensure the students' own consent for participation, their verbal and non-verbal expressions were carefully considered during the sequence of lessons in the classroom.

4.1 The sequence of lessons

The learning design sequence of the combinatorial task was divided into three lessons. The first lesson started with the teacher showing the students three toy bears in three different colours and explaining the dilemma of choosing seats on the sofa (setting). Then the students were divided into pairs to solve the task together (the primary transformation unit). The students were given paper and coloured pens. With these, they were expected to create representations based on the toy bears, thus transforming from one mode of representation (manipulatives) to another (visual representation on paper). The students could choose how they wanted to document their solutions (e.g., drawing pictures of bears or representing the bears with lines or dots). The first lesson ended with the teacher gathering all the students and inviting some of the pairs to present their documentation (the secondary transformation unit). During the presentation, the teachers posed questions focused on similarities and differences in the students' documentations, how many different solutions (permutations) the students had found, how they had structured their solutions, and whether and how they knew that they had found all permutations (referred to as "combinations" during instruction).

The second lesson was conducted the following day, with students working in the same pairs as in the first lesson. This lesson was led by one of the researchers, who asked the students to re-design the solution they had come up with the day before (setting) in an animation. When creating the animation, the students used the documentation they had produced the previous day (the primary transformation unit). The toy bears were photographed because the students wanted to attach the heads of the bears to the bodies in the application used to create the digital animations. After the animations were created, the students and the researcher watched them together (the secondary transformation unit).

The third and final lesson was conducted on the same day as the second lesson and with the same pairs. The students were reminded of the task they had worked on in the two previous lessons, and they were asked to pose a similar task to a peer (setting). The students were free to document their task using any material they wished (the primary transformation unit). In some cases, the students asked the teacher to complement the documentations of their tasks by writing the posed question.

4.2 Analysis

The empirical materials analysed were the video documentations from the three lessons together with the students' paper-and-pen documentations from the first lesson, the animations from the second lesson, and the posed tasks from the third lesson.

To analyse these empirical materials, we used questions developed by Wagner and Herbel-Eisenmann (2009). First, we asked: Who does mathematics, and when in the sequence do they do it?? By asking this, we were able to identify when the actors engaged in the problem-solving and problem-posing tasks. Second, we asked: What mathematical processes are the students engaged in? By asking this, we were able to identify the different actions the students performed. Finally, we asked: Who are these students doing these things for, and why? By asking this, we could identify what was valued by the students and the different roles that were available and taken by the students in the collaboration.

5 Results

In the results, one case of two 6-year-old students is used to illustrate whether and how students' positioning when collaborating influences their meaning making in mathematics.

5.1 Lesson one

Felicia and Anthony are sitting next to each other. On the table in front of Felicia there is one piece of paper, one lead pencil, and three coloured pens: one blue, one red, and one yellow – the same colours as the plastic bears the teacher showed when introducing the task. Anthony says to Felicia that she needs to draw a big sofa, which she does. Felicia then finalises the drawing of the first permutation.

> Felicia: Now we are done.
> Anthony: No, we cannot have only one [solution]. We cannot have only one. It is not only one.

At the same time the teacher comes by. Felicia shows her their paper saying, “We are done.” Anthony says “No.” The teacher asks, “What was the task? In how many different ways [can the bears sit on the sofa]?”

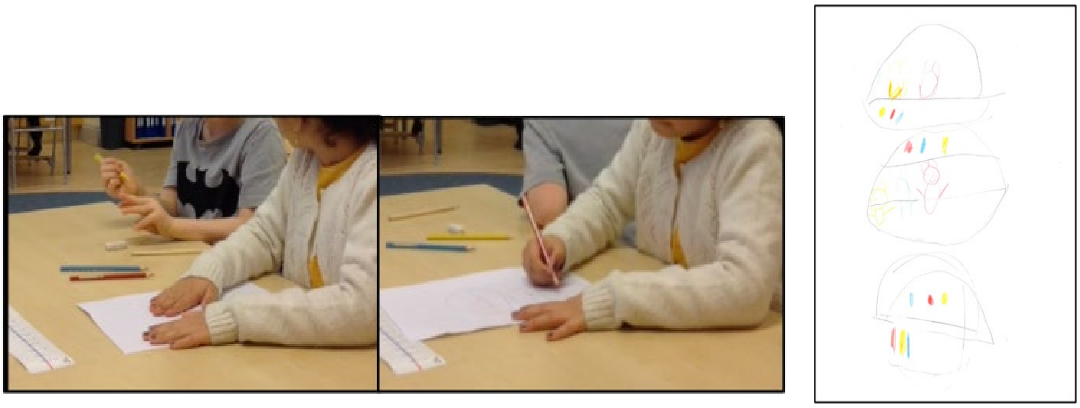
> Anthony: It was only Felicia who said it.
> Teacher: You have to agree.
> Anthony: This is one way [they can sit].
> Teacher: Exactly, this is one way. It is not ready. The question is in how many ways. You have to agree.

The teacher walks away. Anthony starts to draw a new sofa. Felicia takes the paper from him and complains about the way he has drawn the sofa. The teacher walks by and takes the paper from Felicia and gives it to Anthony. Anthony draws a new permutation while talking to Felicia, saying that he is drawing dots instead of bears. Felicia is watching what he is doing. Then he gives the paper to Felicia, saying, “Now you can draw the next one.” While she is drawing, he does not look at what she is doing; instead, his back is turned towards her, and he is looking around in the classroom. When Felicia has finished, Anthony looks at the paper and says, “No, now you drew in the same way [...] Now we did the same thing [solution] again.” Then he shows Felicia how to draw a new permutation and says, “You must put the yellow [bear] in the middle.” When they have three permutations, he turns to the teacher and asks, “Are there three ways or are there more?”

> Teacher: How many [permutations] have you found?
> Anthony: The yellow [bear] has sat in all the places [on the sofa], the blue has sat in all the places, and the red has sat in all the places.
> Teacher: Okay!
> Felicia: Is there one more way?

The teacher walks away without answering. Anthony then concludes that “There are more ways because otherwise she would not do that.” After giving it some thought, he draws three more solutions on the paper while Felicia looks at what he is doing. Thus, their final documentation shows six permutations.

Figure 1. a-b) The students working on the task. c) The students' documentation of the solutions.

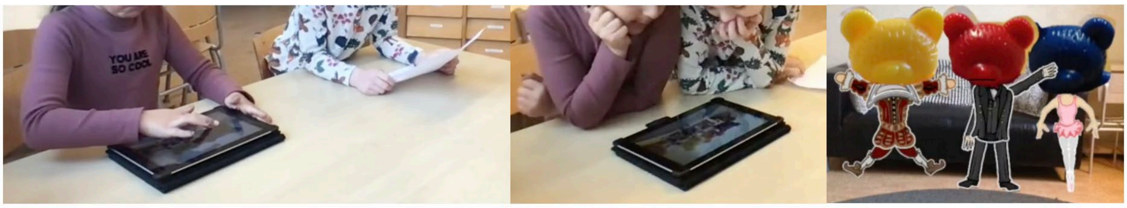


During lesson one, Anthony and Felicia follow two different storylines. Felicia initially follows a storyline where she appears to believe that they have completed the task with one permutation. Anthony follows a storyline that focuses on drawing new permutations, sure that there must be more than one. Then, the teacher introduces a storyline in line with Anthony's by promoting the need for multiple permutations. Also, she takes the paper from Felicia and gives it to Anthony. The teacher's action offers Anthony a position as someone who knows how to solve the task. Anthony positions himself by initiating the suggestion to draw a big sofa and later to draw new permutations. He aligns himself with the teacher's expectation of finding multiple solutions by drawing new permutations and insisting on the need for more than one solution. Felicia initially aligns herself with Anthony's position but later resists his ideas, complaining about the way he draws the sofa and suggesting a different approach. However, she fails to draw new permutations. To summarise this part of the sequence of lessons, both actors are engaged in the problem solving, but only Anthony has grasped the mathematical content of combinatorics. Further, the students value different things, where Anthony (and the teacher) values finding new permutations while Felicia values drawn figures. These two roles can be understood as the two available based on the actions of the teacher and Felicia not understanding the mathematical content.

5.2 Lesson two

Felicia and Anthony are sitting next to each other with their documentation from the day before. The researcher asks if they remember what the task was about. Both students explain that it was about how many different ways three bears could sit on the sofa. The researcher confirms this and says they will record a story about how the three bears can be seated on a sofa. Anthony says, "Yes, like, once upon a time there were three bears. Then you say, first the blue sat, then the red sat, then the yellow sat." The researcher confirms what Anthony says. Then Anthony points at the tablet on the table and says, "I am not good at that" (they have been shown the application before). At first, Anthony has both the paper with the documentation and the tablet, and he asks Felicia, "Am I to do everything?" Felicia nods. But when Anthony starts recording, she takes the tablet, wanting to help. But then something happens with the application/recording, and they have to start all over. The researcher helps them start over by saying, "Is Felicia to do [the animation] and you tell [the story]?" Anthony confirms this by nodding. Anthony holds the documentation and tells the story, while Felicia moves the figures in the animation based on his story (Figure 2a). On one occasion he corrects Felicia by repeating what he said before and looking at her at the same time: "The yellow [bear] sat last [to the right], I said." When they have finished, Felicia looks at the researcher and asks, "Was it good?" The researcher asks them what they think, and Felicia answers, "Yes, no one disappeared." She is referring to the creation of the animation where the figures must be kept within a frame as they otherwise disappear. After this, they look at their animation together (Figure 2b and 2c).

Figure 2. a) The students create their animation. b-c) The students look at their animation.



Above, the storyline revolves around recording a story about the three bears. Anthony immediately suggests a traditional storytelling format, while Felicia engages in animating the story. Anthony's storyline involves hesitation with technology and his subsequent role as the storyteller. As the storyteller, he guides Felicia in creating the animation. Anthony positions himself as someone who contributes to the task by suggesting how the story should be told and at the same time expressing his limitations with technology. He aligns himself with the task by offering suggestions for how the story should be told and ultimately taking on the role of storyteller. Felicia's storyline focuses on her role in creating the animation. She positions herself as someone who actively participates in the task by moving the figures in the animation based on Anthony's storytelling. Felicia aligns herself with the task and seeks feedback on the final product. The collaborative nature of the task highlights the interdependence between Anthony and Felicia as they work together to complete the animation under the guidance of the researcher. To summarise this part of the sequence of lessons, both actors are engaged in the recording. Still, as Anthony is the one who grasped the mathematical content of combinatorics, he positions himself as the storyteller. At the same time, he positions Felicia as the one who knows how to work with the application. Both students in this sequence value the same thing, that is, making a good animation, and there are two different roles available and needed in the situation.

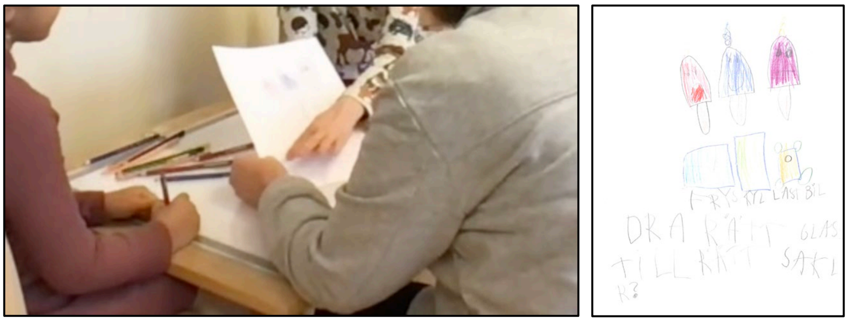
5.3 Lesson three

Felicia and Anthony are seated across from each other at a table. On the table, there is a white paper and several coloured pens. The students have been told to pose a task similar to the one they have been working on during the two previous lessons.

> Anthony: Should we do ice-cream cones and see how many kinds of sprinkles you can have on them?
> Felicia: Didn't the teacher say it was to be about bears?
> Anthony: No, you do not have to [have bears in the task]. We are supposed to do a similar task.

Felicia then reaches out to the teacher and asks, "Was it [the task] to be about bears?" The teacher answers, "What did you work on before?" Anthony looks at the teacher and says, "Then we should not do one with bears, Felicia." They decide to make a task with ice creams, and Felicia starts to draw an ice cream. Anthony wants to show her what a cone should look like, but she refuses to hand the paper and pen to him. When she has drawn one ice cream, though, she does hand the paper to Anthony, who continues to draw. Felicia, however, does not accept his drawing. Instead, she takes the paper and draws the rest of the ice creams. Anthony suggests a posed question on combinations of ice cream flavours and toppings. However, Felicia refuses this solution. Then the teacher comes by, and Anthony tells her about another task and tells the teacher what she should write on their paper (Figure 3a and b).

Figure 3. a) Anthony tells the teacher how she should pose the problem in writing on their paper. b) The posed task: *Draw a line from the correct ice cream to the correct ice-cream car.*



In this final lesson, the storyline initially revolves around negotiating the task, with Anthony suggesting a posed task showing that he understands the task and the mathematical content. Nonetheless, he decides to go along with Felicia's idea when she seeks clarification from the teacher. Anthony's storyline involves suggesting a task centred around ice-cream cones, while Felicia's storyline centres on her role as the illustrator, initially refusing Anthony's guidance but eventually accepting it. Anthony initially positions himself as someone who suggests a task and later as a guide, offering instructions to Felicia as she draws the ice creams. Felicia initially positions herself as someone who seeks clarification from the teacher, indicating a desire to adhere to the instructions given. To summarise part of the sequence of lessons, both actors are engaged in the problem posing, but it is still apparent that only Anthony has grasped the mathematical content of combinatorics. Further, the students still value different things, where Anthony values posing a task with the correct content while Felicia values nicely drawn figures. As before, these two roles can be understood as the two available based on the actions of the teacher and Felicia not understanding the mathematical content. The result is a posed task without either the same content or the same context as the original task.

6 Discussion

In this paper, one case of two 6-year-old students is used to illustrate whether and how students' positioning when collaborating influences their meaning making in mathematics. Overall, using positioning theory, the analysis shows how Anthony and Felicia position themselves and each other during the three lessons. Felicia follows her usual storyline, portraying herself as the well-behaved girl who can draw and write nicely and who listens to the teacher's instructions diligently. In the sequence of lessons, it becomes evident, however, that she has not grasped the task or the mathematical content, unlike Anthony. He understands the task and works mathematically to find the permutations, which is not appreciated by Felicia. Maybe this can be explained by the fact that Anthony usually does not follow a storyline where he is the one who understands the tasks and listens to what the teacher tells him to do. The "usual" storylines of these students influence how they negotiate their roles and relationships, and how they construct meaning through their interactions. When they are to pose a task, Anthony again shows that he understands the mathematical content. However, Felicia does not, and since the teacher has not heard what Anthony suggested regarding the ice creams, their posed task is not in line with the original task. Thus, their view of themselves and each other as learners of mathematics may be influenced by and may influence their positioning and the teacher's way of positioning them, reflecting the dynamic nature of social interactions. In this case, their positioning during collaboration hinders both students' meaning making in mathematics.

The example selected here is one where collaboration does not impose meaning making in mathematics. However, this could have been counteracted if the teacher had heard that Anthony understood the mathematics content and then helped Felicia understand the task. Then the collaboration could have developed differently. In the second sequence, there were two possible roles that were both needed. This contributed to both students participating actively in solving the task, but still without Felicia fully understanding the content. The fact that Felicia still did not understand the content after two lessons also affected meaning making in mathematics when the students were working on problem posing. Thus, in the example in this paper, the often-encouraged collaboration between students during problem solving and problem posing (Liljedahl, 2021) did not lead to meaning making in mathematics. This does not mean that we believe that collaboration should be avoided. But, while young students need to become familiar and comfortable with problem solving and problem posing (English, 2004; English & Sriraman, 2010), when and how they collaborate needs to be further investigated. One conclusion drawn from the empirical example in this paper is that, even if students are not told how to solve a task (not valued in problem solving), the teacher needs to ensure that all students in a collaborating group understand what the task is about. Otherwise, the meaning making in mathematics of all collaborators may be negatively influenced.

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