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Research article

How does students' participation in a problem-solving project frame their view of what it means to be taught and to learn mathematics?

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Abstract: The mathematics teaching that young students encounter affects not only the mathematics they are given the opportunity to learn but also their view of what mathematics is, how mathematics is taught, and how they view their own ability to learn mathematics. In this article, we explore how six-year-old students' participation in an intervention focused on problem solving and problem posing is associated with differences in their views of what it means to be taught and to learn mathematics. We compare drawings of mathematics classrooms created by students from different classes, some of whom had participated in the intervention and others who had not. The results reveal notable differences in the actors and objects included in the drawings. The control group commonly drew textbooks, teachers, and mathematical symbols, whereas the intervention group also depicted other aspects, such as collaborative settings and manipulatives. Thus, a more diverse view of mathematics education appeared in the drawings of the students who participated in the intervention. We argue that these differences may be related to students' experience with problem solving and problem posing, as well as to critical aspects of these activities, such as creativity and autonomy.

Keywords: problem solving, problem posing, drawing, educational design research, primary mathematics

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1 Introduction

The mathematics teaching that young students encounter affects not only the mathematics they are given the opportunity to learn but also their view of what mathematics is, how mathematics is taught, and their perception of their capacity to learn mathematics. In this article, we set out to contribute knowledge on how six-year-old Swedish students' participation in an intervention on problem solving and problem posing was related to variations in their views of what it means to be taught and to learn mathematics.

Understanding students' views of mathematics education is important because such views shape how students interpret classroom experiences, engage with mathematical tasks, and position themselves as learners. In early mathematics education, these views

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are particularly significant, as they are formed in interaction with initial experiences of schooling and may influence long-term participation and identity development. Previous studies in the MAVI tradition have shown that even young students hold complex and meaningful conceptions of mathematics and mathematics teaching, which can be effectively accessed through drawings (Dahlgren & Sumpter, 2010; Blomqvist et al., 2012). This highlights the importance of examining how classroom practices relate to the development of such views. Given that students' views influence both how they engage with mathematics and how they see themselves as learners, it is important to understand how different forms of teaching frame these views. In particular, examining how participation in specific instructional approaches, such as problem solving and problem posing, relates to changes in students' views can provide insight into how teaching can support more productive and inclusive understandings of mathematics. Thus, studying these relationships is essential for informing the design of early mathematics education.

We conceptualise views as students' expressed situated and communicable perceptions of mathematics education, including how mathematics is organised, enacted, and experienced in the classroom. In line with affect research (e.g., Hannula, 2007; Di Martino, 2019), we treat views as socially and situationally constructed, and as communicable through multimodal expressions such as drawings. Student drawings are treated as multimodal expressions of perspective, allowing researchers to infer values, positioning, and understandings regarding mathematics lessons (Dahlgren & Sumpter, 2010). From a social semiotic perspective, views can be observable as spatial organisations of actors and objects, that is, how students arrange actors (such as students and teachers) and objects (such as textbooks and manipulatives) in pictures related to the teaching of mathematics, and how this affects the composition of the students' perception of the classroom (Kress & van Leeuwen, 2001).

In Sweden, six-year-olds attend preschool class, which is one year of the formal education system intended to provide a smooth transition between preschool and school. In the national curriculum, mathematics is described as a creative, reflective, and problem-solving activity where students are to enhance their skills in problem solving and problem posing, including evaluating different strategies and methods (Swedish National Agency for Education, 2018). Research has shown that young students' perceptions of mathematics (what it is, how it is learned, and who participates) shape their engagement, interest, and developing identities as mathematics learners (Clements & Sarama, 2016; Perry & Dockett, 2008). Studies focusing specifically on students' views or conceptions of mathematics education indicate that young children often express complex understandings not easily captured through interviews alone (Dahlgren & Sumpter, 2010). Drawings, therefore, offer an important methodological tool for accessing early learners' perspectives, which are often communicated visually rather than verbally. This makes the study of six-year-olds' views especially relevant.

Research on early mathematics indicates that young students who engage with challenging problem-solving tasks in school exhibit a strong understanding of mathematical concepts (Hiebert & Grouws, 2007; Liljedahl & Cai, 2021). A meta-study on problem posing showed that problem-posing activities improved students' problem-solving skills and their mathematical achievement, including procedural fluency and conceptual understanding (Wang et al., 2022). Mahendra et al. (2017) also showed that problem posing had greater positive effects on students' conceptual understanding compared to problem solving, but that students' (adaptive) reasoning skills increased more with problem solving.

Even though problem solving and problem posing are emphasised in the Swedish national curriculum, a nationwide assessment of mathematics teaching conducted in 2009 revealed that individual counting dominated mathematics instruction in Sweden, with limited opportunities for students to develop problem-solving competencies (Swedish Schools Inspectorate, 2009). In response to these challenges, an educational design research project on problem solving and problem posing was initiated. This study has been ongoing for more than 10 years in close collaboration between researchers and preschool class teachers (see, for example, Ebbelind et al., al 2026; Palmér & van Bommel, 2021). In the study, the students participate in several problem-solving and problem-posing activities during the school year. The mathematical topics covered in these activities vary, including, for example, combinatorics (e.g., van Bommel & Palmér, 2021), probalility (e.g., van Bommel& Palmér, 2016), and geometry (e.g., Palmér & van Bommel, 2023). Typically, each activity spans two lessons. In the first lesson, students work (usually in pairs) on a problem, and in the second lesson, they are asked to pose a similar task. To set the scene, the problem in the first lesson could be: We are going on a picnic, and you need to prepare some sandwiches. You have two types of bread and three different toppings. How many different kinds of sandwiches can you make (one slice of bread, one topping)? At the end of the activity, the teacher collects various solutions, and a whole-class discussion is held to review selected solutions. The focus of this discussion is both on the mathematical content and the strategies used by the students. In the second lesson, the students are reminded of the original problem-solving task, after which they are asked to pose a similar task.

Mathematics education through problem solving and problem posing, as described above, imposes a different structure of mathematics lessons than the one that is more common in Swedish schools, where students work individually with a mathematics textbook (Swedish Schools Inspectorate, 2009). Based on this background, this study addresses the question: How does six-year-old students' participation in a problem-solving and problem-posing intervention shape their view of what it means to be taught and to learn mathematics?

The article begins by presenting students' views of mathematics education alongside research on problem solving and problem posing in early mathematics. We then describe the intervention and the study context, followed by a detailed methodological account of how student drawings were analysed as expressions of mathematical views. The results are then presented, followed by a discussion that integrates empirical findings with theoretical explanations. Finally, we conclude with pedagogical implications and suggestions for future research.

2 Problem solving and problem posing

Several international studies have shown that if students are to be successful in mathematics, problem solving should be integrated early into mathematics education (see, for example, Cai, 2010; Liljedahl, 2018). Further, problem posing may 'create learning opportunities for all students' (Liljedahl & Cai, 2021, p. 731). Recently, Cai and Rott created a model for problem posing, in which problem posing is seen as a special type of problem solving. In line with Pólya's four phases, they define four corresponding phases for problem posing: orientation, connection, generation, and reflection (Cai & Rott, 2024).

By engaging in problem solving and problem posing, young students can develop an understanding not only of problem solving but also of important mathematical ideas and content (Cai et al., 2022; Cifarelli & Sevim, 2015; Lesh & Zawojewski, 2007), such as conceptual understanding or procedural fluency (Mahendra et al., 2017; Wang et al., 2022). Further, such engagement can also enhance their creativity (Zhang et al., 2024, 2025). In problem posing, the collective or collaborative aspects can be connected to the sociocultural perspective on teaching and learning, offering a way to examine both the process and the product of the task (Cai et al., 2022). The collaborative aspect can be seen through the lens of the teacher organising collective learning, where student engagement, such as peer interaction, is used to scaffold learning (Wang et al., 2022). A recent meta-study on problem posing (Zhang et al., 2024, 2025) showed that studies on problem posing very seldom focus on students below the age of eight (only two of the 26 included studies did so); most focus on older students, including university students. One of the studies on young students investigated the ability of four-, five-, and six-year-olds to ask questions with the purpose of completing a problem-solving task (Legare et al., 2013). The study showed positive correlations between posing what they termed constraint-seeking questions and successful problem solving. In the study, these constraint-seeking questions were contrasted with confirmatory questions (questions that have already been asked) and ineffective questions (questions asked in a way that fails to capture useful information). Furthermore, the study demonstrated that students' ability to generate relevant information by asking questions developed before their ability to use the information generated by their questions to actually complete problem-solving tasks.

There are studies indicating that students' attitudes and emotions play a role in their learning of mathematics (Di Martino, 2019; Hannula, 2016) as well as their interest in the subject (Clements & Sarama, 2016). For example, research has shown that young students' achievement in science, technology, reading, and mathematics is influenced by their interest in and emotional disposition towards mathematics and science (Clements & Sarama, 2016). Further, correlations have been found between students' attitudes, emotions, and performance in mathematics, as well as factors such as mathematics anxiety and feelings towards mathematics and problem solving (Antognazza et al., 2015). Some studies have shown that feelings such as frustration, anxiety, confidence, surprise, and curiosity affect the process of solving non-routine mathematical tasks (Di Martino, 2019; Hannula, 2016), while other studies have found no such correlations (Dowker et al., 2012). In some cases, where correlations are found, these are attributed to cultural differences in students' emotional responses towards mathematical problem solving (Dowker et al., 2019). Thus, the social and cultural contexts in which students learn mathematics may play a crucial role in shaping what they learn, their understanding of mathematics, and their perspectives on mathematics learning (Perry & Dockett, 2008). In previous publications, we have shown that, for early mathematics education, problem solving and problem posing positively influence students' attitudes towards mathematics (Palmér & Karlsson, 2016; Palmér & van Bommel, 2018; van Bommel & Palmér, 2021). For older students, problem posing has a positive impact on their beliefs about problem solving (Stylianides & Stylianides, 2014) and also on their mathematical metacognition and self-efficacy (Chiu & Yang, 2024). When students are given ownership and autonomy regarding the questions to pose, they also have to make decisions about what elements of a task to focus on (Wang et al., 2022), which can, in turn, affect their self-efficacy.

There are significant variations in how mathematics is taught in Swedish primary schools, resulting in differences in students' experiences and perceptions of mathematics (Samuelsson, 2010; Swedish Schools Inspectorate, 2009). Expectations in mathematics education are often implicitly expressed in classrooms, with socio-mathematical norms influencing the learning opportunities available to students (Yackel & Cobb, 1996). These socio-mathematical norms affect students' perceptions of mathematics, which, in turn, influence their behaviour and performance. Furthermore, socio-mathematical norms can vary across mathematical domains. Consequently, students' experiences of problem solving can affect their behaviour and performance when engaging in problem-solving tasks or activities they perceive as such. In a previous study focusing on the implementation of problem solving and entrepreneurship in preschool-class education, interviews with students revealed that while they recognised problem-solving tasks as having distinctive features, only a few demonstrated an awareness that such tasks could be approached and solved in various ways. Additionally, most of the younger students in the study failed to establish a connection between problem solving and mathematics (Palmér & Karlsson, 2016). Thus, changes in mathematics education may not always be noticed in the same way by teachers and students, and implementing problem solving often necessitates a renegotiation and modification of socio-mathematical norms. Further, the existing socio-mathematical norms within a class significantly influence how teachers can successfully implement changes in mathematics teaching in the classroom (Wester, 2015).

3 The intervention and its context

As mentioned, in Sweden, six-year-olds attend preschool class, which is the first year of the formal education system. Since 2014, a longitudinal educational design research study (McKenney & Reeves, 2012) has been exploring and developing a problem-solving and problem-posing approach to mathematics in preschool classes. This has been done in close collaboration between researchers and preschool-class teachers (Palmér & van Bommel, 2021).

Educational design research implies a cyclic process of designing, implementing, and evaluating interventions situated within an educational context (McKenney & Reeves, 2012). Thus, in the intervention, the preschool-class teachers have implemented jointly planned problem-solving and problem-posing activities in their classes throughout each school year. Typically, each activity begins with a short whole-class introduction of the task followed by problem solving in small groups, with the teacher circulating to facilitate discussions and encourage explanations. Following this, various solutions are collected and discussed in a whole-class setting. In a subsequent lesson, students return to the original problem-solving task, and they are asked to formulate a similar task. Given the teachers' prolonged involvement in the study, problem-solving activities developed in previous design cycles are often integrated into their ordinary teaching. Thus, in the study, the students participate in several problem-solving and problem-posing activities during their year of preschool class (for more information, view Palmér and van Bommel, 2021). However, the collaboration ensures that a minimum of six activities each year are conducted jointly across participating classes. At the beginning and end of the school year, the students are asked to draw a picture of themselves having a mathematics lesson. In this article, these drawings are used to examine whether and how the mathematics education offered during the school year affects students' views of mathematics.

4 Method

4.1 Empirical data

The empirical material used in this article is from eight different classes at four different schools. Two classes at each school participated, one attending the intervention (problem-solving class, PG) and one not attending the intervention (Control group, CG). The non-attending classes were chosen because they were parallel classes and thus included students from the same socio-economic areas. These classes were given the same task: to draw a picture of themselves having a mathematics lesson. When students wanted it, the teacher helped them write comments on the drawings. Dahlgren and Sumpter (2010), Hatisaru (2020), and Hannula (2007) point out that young students may have difficulty communicating their conceptions orally and that, therefore, using drawings as tools can provide information that other research methods might not. A total of 107 drawings were analysed, of which 58 were from students in classes participating in the intervention (PG). In line with the national regulations, permission for the students' participation was given by their guardians and by the students themselves (Swedish Research Council, 2017).

4.2 Analytical tools

As already introduced, views are seen as a spatial organisation, and how this affects the composition of the student's perception of the classroom (Kress & van Leeuwen, 2001). In this study, views are not accessed directly but inferred from students' multimodal expressions, specifically their drawings. These drawings are treated as meaning-making artefacts through which students communicate their perceptions of mathematics teaching and learning through the spatial organisation of actors, objects, and activities. Views are operationalised as observable patterns in the way students organise and relate actors, objects, and activities in their drawings. From a social semiotic perspective, meaning is constructed through these spatial and relational arrangements. Thus, students' views of mathematics teaching and learning are inferred from how they depict participation, interaction, and the use of artefacts in classroom settings. In this analysis, actors are defined as human participants (e.g., students and teachers) represented in the drawings, while objects refer to material or symbolic resources such as textbooks, manipulatives, and mathematical symbols. Although objects may structure activity, they are not treated as agents but as resources that shape the representation of classroom practices.

To study the possible effects of problem solving and problem posing on the students' views of what it means to be taught and to learn mathematics, a framework from the social semiotic perspective of multimodality was used. This perspective offers an approach to understanding how individuals, in this case, six-year-old students, communicate within specific social contexts, such as a mathematics lesson. Specifically, it offers a way to identify how individuals communicate visually within interpersonal and institutional settings (van Leeuwen, 2004).

In this article, we explored how students frame their view of teaching and learning mathematics. 'Framing' is a concept specific to visual communication, that is, the pictures from the students. By 'framing,' we referred to how actors and objects within a visual composition are composed or not. Visual composition can, for example, be separated or linked. Separation may be achieved through framing lines, boundaries created by objects such as different areas in a classroom, empty space, or single actors and/or objects. Conversely, actors and objects can be connected by the absence of such boundaries. The key idea is that actors and objects are perceived as distinct and independent, possibly serving as contrasting units of meaning, while connected elements are seen as related, forming continuous or complementary parts (see figure 1 for an example) (Kress & van Leeuwen, 2001).

Multimodality has emerged in the past decade and is an interdisciplinary approach that recognises communication and representation as extending beyond language (Kress & van Leeuwen, 2001). It is used for purposes such as the systematic description of semiotic resources and their potential (e.g., the specific roles that digital tools play, Ebbelind et al., 2023); a multimodal investigation of interpretation and interaction within specific environments (e.g., textbooks, Danielsson & Selander, 2016); the identification and development of new semiotic resources and innovative applications of existing resources in designed environments (e.g., educational design Patron et al., 2024); and contributions to research methods for the collection and analysis of data and environments within social research (e.g., Jewitt, 2009). Further, multimodality offers concepts, methodologies, and frameworks for collecting and analysing visual, embodied, and spatial aspects of interaction and environments and their relationships (van Leeuwen, 2004). This study utilises one of these frameworks, which will be discussed below.

Using a social semiotic perspective of multimodality, the analysis focused on available semiotic choices and how these were utilised in the drawings of a mathematics classroom. The meanings associated with these choices were then related to previous social interactions in the classroom. The analytical tool used (Table 1) is inspired by a tool developed by Danielsson and Selander (2016). The selection of this framework is motivated by its focus on how semiotic resources are organised to create meaning in educational contexts. Although originally developed for textbook analysis, the authors explicitly state that the model can be used for texts across all school subjects, including those other than printed textbooks, with minor adaptations (Danielsson & Selander, 2021). The emphasis on relationships between actors, objects, and values makes it suitable for analysing student-generated representations of classroom practices. In this study, the framework provides a structured way to connect visual features of the drawings to interpretations of students' views.

The framework was adapted in two ways. First, the original focus on multiple modalities was reduced to a single modality (drawing). Second the emphasis was on spatial organisation and composition in stead of the coherence between different modalities.

Table 1. Analytical tool.

	Multimodal focus	**Classroom focus**
General structure	What objects are presented? What does each one of the resources express?	What classroom views can be interpreted?
Arrangement of textual parts	How are objects and entities arranged?	Reflection about how different resources interact and what appears to be central.
Figurative language	How are actors positioned in the classroom?	What does this tell us about teaching?
Values	Explicit and implicit values	What are the implications for the view of mathematics?

The analysis was conducted iteratively. First, all drawings were examined to identify recurring actors and objects. Second, these elements were categorised according to the analytical framework. Third, each drawing was coded in relation to the identified categories (e.g., presence of actors, types of objects, and their arrangement). Ambiguous cases were discussed among the authors until agreement was reached, ensuring consistency in the coding process.

By analysing the general structure of the drawings, we notice how students position themselves in certain activities concerning mathematical objects. Here, we start by asking what the drawing is about, how it is arranged, and which objects are present. At this stage, the drawings are examined at a relatively general level regarding layout and content. This is an appropriate starting point for meta-textual discussions of the classroom views. What resources stand out, what roles do different types of entities (persons and artefacts) seem to play, and is there an expected classroom view? An essential aspect of the multimodal analysis is the relationship between the different objects, in this case, persons and artefacts, and the various ways these persons and artefacts are positioned. We ask to what extent the different drawings provide the same, overlapping, or additional/complementary information. We then look for evidence of teaching strategies that can inform how teaching may be conducted in these classrooms. Finally, we analyse how the drawings express the values of a mathematics classroom to consider implications for the students' views. One drawing from the non-attending classes could not be classified in this respect.

5 Results

This section reports on the analysis following the structure outlined in Table 1 in order to answer the question of whether six-year-old students' participation in an intervention on problem solving and problem posing affects their views of what it means to be taught and to learn mathematics.

5.1 General structure

The first category in our analytical tool focuses on the actors and the objects presented. The actors present in the drawings are students working, peers attending, teachers attending and whole-class activities; 36.2% of the PG drawings contain actors compared to 22.5% in the CG. However, what stands out is that, at most, one actor is present in the CG drawings (Figure 1: left), whereas in eight out of 21 PG drawings, multiple actors are present (Figure 1, right).

Figure 1. Example of one actor (left) and several actors (right).

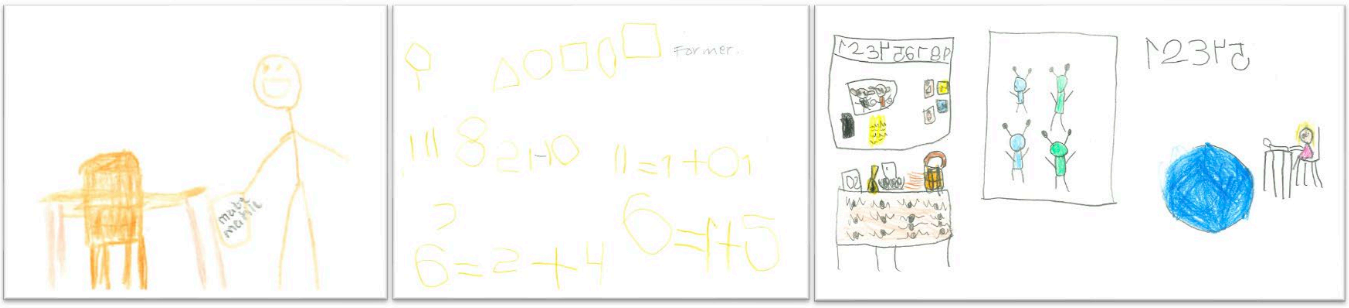
Besides the actors, the objects in the drawings were categorised. These objects were the mathematics textbook, mathematical symbols, workspace (Figure 1, left), whiteboard, gathering place (for example, the blue round carpet in Figure 2, right) and manipulatives.

Table 2. Objects in the students' drawings.

	Actors	Text-book	Math symbols	Workspace	White-board	Gathering	Manipulatives
CG	11(22.5%)	19(38.7%)	31(63.3%)	12(24.5%)	2(4.0%)	-	-
PG	21(36.2%)	11(19%)	36(62.1%)	20(34.5%)	8(13.7%)	12(20.7%)	23(39.7%)

The mathematics textbook is present in 38.7% of the CG drawings (Table 2), often together with a workspace for a single student (Figure 2, left). In contrast, 19% of the PG drawings have a mathematics textbook (Table 2). A large proportion of the drawings include mathematics (63.3% CG, 62.1% PG, Table 2) as mathematical symbols such as numbers, geometry, patterns, objects representing small and large, and objects symbolising categorising. However, 45% of the CG drawings include only mathematics without any actors present (Figure 2, middle) compared to 13.7% in PG drawings. In most PG drawings, mathematics is related to actors or other objects (Figure 2, right). Students in the CG did not draw any gathering sites or manipulatives, whereas students in the PG included gathering sites (20.7%) and manipulatives (39.7%) in their drawings. The gathering site and manipulatives were illustrated in the drawings associated with teaching and learning mathematics. Most mathematical instruction takes place at the gathering sites.

Figure 2. Objects in the drawings.



5.2 Arrangement of textual parts

The arrangement of textual parts focuses on what appears to be central in the drawings. Combining the different objects identified and categorised in the general structure of the drawings, six categories were developed regarding the arrangement of these objects (the textual parts): Mathematical symbols (without a student, textbook, or any other objects, as in Figure 2, middle); The mathematics textbook (without a student or any other objects, as in Figure 3, left); Students working with mathematics in the mathematics textbook (Figure 1, left); Students working with mathematics (other than with the textbook, as in Figure 3, middle); Objects from the classroom related to mathematics (Figure 3, right). Each drawing was coded into one of these six categories.

Figure 3. Objects in the drawings.

Table 3. Categories of arrangement of objects (rounded percentages)

	Math symbols only	Textbook only	Student & textbook	Student & math	Classroom objects	Group & pair work
CG	30(61.2%)	9(18.4%)	8(16.3%)	-	2(4.0%)	-
PG	15(25.9%)	3(5.2 %)	3(5.2%)	6(10.3%)	19(32.8%)	12(20.6%)

Most CG drawings contain mathematical symbols only (61.2%) (Figure 2, middle), or the textbook (16.3%) with or without students (18.4%). That is, around 96% of the CG drawings are centred around the textbook and mathematics symbols. The PG drawings are more diverse. The mathematics textbook is focused on in 10.4% of the drawings, but only 5.2% show the textbook without other objects. Classroom objects such as white-boards, manipulatives, and carpets as gathering spaces are visible in 32.8% of the PG drawings (Figure 3, right) compared to only 4.0% of the CG drawings. Mathematics as a collaborative activity, that is, drawings indicating group or pair work, is visible only in the PG drawings (20.6%). One observation regarding the PG drawings that include objects from the classroom (32.8%) is that they include manipulatives that can be used when doing mathematics, whereas none of the CG drawings include manipulatives.

Thus, there is a difference between the groups regarding individuals and artefacts, and the ways these are positioned in the drawings. PG drawings include more objects than CG drawings. Further, they include a variety of objects, providing more information. CG drawings depicting a workspace all show a fronted classroom; this is not the case in any of the PG drawings.

5.3 Figurative language and values

The last two parts of the result focus on how the actors are positioned or not positioned, expressed through figurative language in the drawings and on the explicit and implicit values that might stand for specific views of mathematics.

Table 4. Positioning of objects or actors in the drawings

	CG	**PG**
Objects representing mathematics	41(84%)	36(62)%
Actor working with textbook	8(16%)	3(5.2%)
Actor/s working with mathematics	n.a.	19(32.8%)

In the PG drawings, students depicted themselves to a large extent as participants in a mathematical setting. In 32.8% of the PG drawings, they positioned themselves as actors working with mathematics, and in an additional 5.2%, they positioned themselves as working with textbooks. For the CG, the actors are visible in only 16% of the drawings and only working with textbooks. A focus solely on mathematics is visible in 84% of the CG drawings compared to 62% in the PG drawings. This difference reflects different views on mathematics.

5.4 Summary

The results suggest that the mathematics teaching young students encounter is reflected in differences in their representations and perceived classroom practices. We recognise students as participants in mathematical settings where they collaborate in various ways. One could say that the drawings reflect a problem-solving approach to teaching. While mathematics teaching and learning appear to be a shared endeavour to a great extent in the PG drawings, this is not the case in the CG drawings. In the CG drawings, it is evident that there is a significant focus on the mathematics textbook and the representation of numbers. Here, the actors work alone, and mathematics teaching is based on the textbook as the primary artefact.

In summary, the analysis of the drawings shows differences between the drawings from the two groups. For example, the mathematics textbook and mathematical symbols dominate the CG drawings. In contrast, most PG drawings relate mathematics to the collaboration among several actors and objects other than the textbook, such as manipulatives. Further, all depictions of a workspace in the CG drawings show a fronted classroom, whereas the PG drawings do not. Thus, the mathematics education the students in the two groups have encountered appears to be related to differences in students' views of what it means to be taught and to learn mathematics. The following discussion explores possible interpretations of these patterns.

6 Discussion

The findings show that students who participated in the intervention represented mathematics classrooms in more varied ways compared to students who did not participate, particularly through the inclusion of multiple actors, collaborative arrangements, and diverse artefacts. The discussion elaborates on five themes capturing specific aspects of problem solving and problem posing that might explain the diversity: 1) Varying strategies; 2) Asking questions and posing tasks; 3) Collaborating and sharing experiences; 4) Autonomy; 5) Creativity.

6.1 Varying strategies

The general structure of the drawings showed a diversity of objects and actors. Objects and actors were used to a larger extent to represent mathematics and a mathematics lesson in the PG compared to the CG. One possible explanation for this may be that, when young students work on problem solving, they are expected to use various strategies, such as making drawings, searching for patterns, working backwards, making lists, dramatising, making tables and diagrams, guessing and testing, simplifying, and/or using manipulative materials (Lesh & Zawojewski, 2007). Similarly, problem posing requires an openness to various strategies (Wang et al., 2022). Thus, learning to use such strategies lies at the core of problem-solving and problem-posing activities, which, in the end, develop young students' skills to represent mathematics in a variety of ways (Lesh & Zawojewski, 2007). In this process, students can develop representational competence (Mulligan & Mitchelmore, 2009).

In this way, young students, through participating in problem-solving and problem-posing activities, may develop an understanding not only of problem solving and problem posing but also of important mathematical ideas and strategies, which in turn may enhance their ability to draw their mathematics classrooms in an advanced and diverse way. Furthermore, problem posing enhances students' metacognitive skills and self-efficacy (Chiu & Yang, 2024), which might enable students to take a metaperspective on their mathematics lesson, resulting in a more holistic view that encompasses more objects and actors when they draw.

6.2 Asking questions and posing tasks

An important phase of problem solving (and problem posing) is understanding the task, and students must learn to pose purposeful questions to enhance their chances of solving the task. They also need to pose questions to elicit new and relevant information that could assist with solving the task (Legare et al., 2013). In the model for problem posing by Cai and Rott (2024), the connection phase specifically deals with questions to ask. These connections can concern mathematical representations or real-life contexts, but can also concern specific information given in a task. When posing tasks, students may develop a more nuanced and refined view of what a task entails (Legare et al., 2013), as they must pose purposeful questions to enhance their chances of solving the task. This more comprehensive and refined view is reflected in the variety of objects and aspects present in the PG drawings.

In the drawings, the real-life context is requested and denoted in greater detail by the students in the PG, who include many more details. This representational richness may be linked to the students' practice in posing tasks, a practice that likely fosters more refined and contextually grounded conceptualisations of mathematics. For young students, this is particularly important, as drawings function as a primary means of communication, enabling them to express aspects of their experiences and emerging views of mathematics that may not yet be fully verbalised (van Bommel et al., 2025).

6.3 Collaborating and sharing experiences

The interaction between the textual parts (objects and actors) and their arrangement differs in the PG and CG drawings. In the drawings from the PG, the students are depicted as actors with and without the teachers, but in the CG drawings, teachers do not appear with the students. In other studies involving young students (Khalid et al., 2020; Tarim, 2009), their problem-solving abilities were positively developed when collaborative learning was implemented. This improvement was observed as students became better at listening to others' ideas, sharing them, and taking responsibility for the group's collective work. The teacher continued to play a crucial role in the success of the collaborative learning approach by assembling effective groups, presenting tasks, providing materials, assisting student groups with their work through questioning, and offering feedback on solutions (Tarim, 2009). Further, peer interaction can be seen as a scaffolding strategy supporting problem solving (Wang et al., 2022). Thus, collaborating and sharing experiences can influence who is put forward as an actor in mathematics classrooms. The design of the lessons in the project may have enabled the students to develop a view of mathematics where they are actors collaborating with others, which may explain the differences between actors in the PG and CG.

Young students often tie collaboration to concrete and observable actions, such as working with peers and shared materials, which are readily expressed through drawings rather than verbal explanations (Dahlgren & Sumpter, 2010; Hannula, 2007). This may explain why collaborative arrangements and multiple actors become particularly visible in the PG drawings, as young students tend to represent participation through situated and activity-based interactions rather than abstract descriptions of learning (Kress & van Leeuwen, 2001).

6.4 Autonomy

The drawings differed in the positioning of the actors, mostly in that CG drawings showed teachers in front of a whiteboard, and PG drawings showed collaborative environments with multiple students. Klaassen and Doorman (2015) emphasise that problem posing can attribute agency and autonomy to students, which may influence the roles and relationships between teachers and students. For example, when posing tasks, instead of seeking information, students choose and provide information. Instead of answering questions, they formulate self-selected questions. Such a sense of ownership can also contribute to the development of creativity ‘by allowing them [students] to make their own creative choices about some elements of the problem’ (Wang et al., 2022, p. 268). Thus, a sense of autonomy may explain the positioning of actors in the PG and CG drawings and also allow for more detailed and refined drawings.

For young learners, autonomy is likely to be experienced and expressed in tangible ways, such as choosing actions, materials, or roles within an activity, rather than as an abstract notion of independence (Clements & Sarama, 2016; Perry & Dockett, 2008). This may account for why autonomy is reflected in the PG drawings through the positioning of multiple active students and varied activities, indicating that six-year-olds represent agency primarily through visible participation and action (Clements & Sarama, 2016).

6.5 Creativity

The number of objects and actors varied across the drawings, and their arrangement relative to one another also differed. In the PG, multiple drawings showed actors working with mathematics in collaborative settings. In contrast, the CG drawings mostly showed actors sitting at a desk and working with the textbook. Expectations in mathematics education are often implicitly expressed in classrooms, with socio-mathematical norms influencing the learning opportunities available to students. These socio-mathematical norms impact students' perceptions of mathematics, which, in turn, influence their behaviour and performance (Yackel & Cobb, 1996). Mathematics teaching approaches in Swedish primary schools exhibit significant variation, resulting in differences in students' experiences and perceptions of mathematics (Samuelsson, 2010; Swedish Schools Inspectorate, 2009). Furthermore, socio-mathematical norms and students' perceptions can vary across mathematical domains. When students pose questions, this can open up 'creative adventures' (Cai et al., 2022, p. 121) and enhance students' creativity (Zhang et al., 2024, 2025).

In a study conducted by Khalid et al. (2020), challenging problem-solving tasks similar to those used in our study were implemented in early mathematics education, with the specific aim of developing students' creative abilities (fluency, flexibility, originality, and elaboration). The results indicated that the challenging problem-solving tasks enhanced the problem-solving skills and the creative abilities of the students who worked on them, compared to students in a control group who did not work with problem solving. In the study, students worked in small groups, where they shared and exchanged ideas. This collaborative approach increased students' confidence in solving tasks creatively rather than focusing solely on finding a solution.

Also, Pehkonen et al. (2013) explored creativity in problem solving, particularly in open problem-solving tasks. These include everyday problem-solving tasks, tasks with multiple possible answers, tasks without a specific question, projects, investigations, and posing tasks. In the study, students' solutions were categorised based on creativity, and the results showed that open problem-solving tasks contributed to creativity. Additionally, the study highlighted the significance of the teacher's attitude towards problem solving and open problem-solving tasks for successful learning outcomes. Thus, creativity might explain differences in who (actors) and what (objects) interact in the drawings in our study.

An important aspect of these findings concerns the age of the participants. For six-year-old students, drawings function as a primary means of communication, enabling them to express aspects of their experiences that may not yet be fully verbalised. The observed differences between groups therefore provide insight into how early classroom experiences may shape emerging views of mathematics at a stage where such perspectives are still developing. Further, they provide insight into how these early-stage learners represent mathematics in ways that differ from older students, particularly through concrete, activity-based and spatial representations"

Conclusion

This article examines how their participation in an intervention focused on problem solving and problem posing influenced six-year-old students' views on what it means to be taught and to learn mathematics. This was accomplished by comparing drawings of mathematics classrooms created by students from different classes, some of whom had been engaged in the intervention (PG) while others had not (CG). A total of 108 drawings were analysed. The CG drawings primarily depicted mathematics textbooks, the teacher, and mathematical symbols. In contrast, the PG drawings presented a more comprehensive and refined view of mathematics education, including collaborative settings and manipulatives. The multimodal analysis indicates that students who participated in the intervention appear to express a morecomplex view of mathematics education.

On a general level, students' involvement in the project appears to be associated with differences in their view of the mathematics that could be learned but also of what mathematics is and how it is taught. The roles and relationships between teachers and students in these classrooms differ, as well as the emphasis placed on the structure of classroom activities. Students in PG related more with group work, resulting in a greater number of actors appearing in their drawings. Another observation is that drawings from the CG largely featured mathematical symbols and the textbook as an object (96% in total). In contrast, the PG drew manipulatives that can be utilised in mathematical activities, suggesting that students in PG have more semiotic choices available when learning mathematics. This indicates that they have had more opportunities to make these choices and, consequently, to develop their representational competence. In the article, these results are attributed to PG students' experiences with problem solving and problem posing, experiences that have promoted 1) Varying strategies; 2) Asking questions and posing tasks; 3) Collaboration and shared experience; 4) Autonomy; and 5) Creativity.

As highlighted in the methodology section, one limitation of the study is that PG teachers might influence their CG colleagues. Despite this, we observed striking differences between the two groups. After one year of formal schooling, the students in the PG possessed a more comprehensive and complex view of what it means to be taught and to learn mathematics than those in the CG. As a pedagogical implication, the results suggest that mathematics education incorporating problem solving and problem posing can cultivate a positive and diverse understanding of mathematics among young students.

Research ethics

Author contributions

J.v.B.: conceptualization, formal analysis, funding acqusition, investigation, methodology, validation, writing -original draft preparation, writing - review and editing
A.E.: conceptualization, data curation, formal analysis, funding acqusition, investigation, methodology, project administration, validation, writing - original draft preparation, writing - review and editing
H.P.: funding acqusition, investigation, methodology, validation, writing - original draft preparation, writing - review and editing

All authors have read and agreed to the published version of the manuscript."

Artificial intelligence

Grammarly and Microsoft Copilot were used for language editing to improve grammar, clarity, and coherence; all content and conclusions remain the authors' responsibility.

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Data availability statement

Data are unavailable due to privacy or ethical restrictions, as specified in the ethical approval granted by the Swedish Ethical Review Authority (Dnr: 2024-07309-02).

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Conflicts of Interest

The authors declare no conflicts of interest.

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