Teachers' support for children's mathematical learning through interactions while playing with a coding toy

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This study examines how early childhood education and care teachers can support children's mathematical learning in the context of playing with a coding toy (a robot). Video recordings of the interactions that occurred between a teacher and four 3- to 5-year-old pupils while they played with a robot (three hours per week over the course of a month) were analysed based on the theoretical framework of semiotic mediation for mathematics education. The results highlight the fact that the coding toy can be viewed as an artefact for accomplishing a didactic mathematical objective through teacher support, including factors such as problem-solving, counting and measuring.

Research has identified play as a preferential channel for stimulating children's interests and developing their skills and competencies (Singer et al., 2006; Pramling et al., 2019; Pramling Samuelsson & Johansson, 2006), including those related to mathematics (Vogt et al., 2018). In the 21st century, many young children use a combination of nondigital and digital toys and tools in their play practices (Edwards et al., 2020; Fleer, 2019; Kewalramani et al., 2020), and the spheres in which technology and traditional toys are both present overlap (Fleer, 2019). Recent studies have shown that among several types of play, types that involve digital toys can be considered to constitute an important stimulus for the development of 21st-century skills, such as reasoning and problem-solving skills (Çiftci & Bildiren, 2020; Granone & Reikerås, 2021), spatial understanding (Palmér, 2017) and counting (Mowafi et al., 2019). Playing with digital toys, such as coding toys, enables children to develop different ways of thinking about problems and solutions (Turan & Aydogdu, 2020), thereby enhancing their structured thinking, which is also known as *computational thinking* (Wing, 2006). Coding toys are a specific type of digital toy designed

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to help young children learn computer programming (Clarke-Midura et al., 2021). An important point that has been highlighted in the literature is that technology cannot be viewed as a tool that is effective on its own (Quintana et al., 2004; Reiser, 2004). Rather, teachers and technology are perceived as working together to support children's learning (Plowman et al., 2010), and the importance of the teacher's role has been highlighted in the literature (Wang et al., 2021), including in cases in which mathematics is the subject of learning (Niess, 2005, 2006).

The present study was conducted within the context of Norwegian early childhood education and care (ECEC). Although several studies have explored the broader diffusion of technology in ECEC in Norway (Undheim, 2021), research that specifically links technology with mathematics learning, particularly with a focus on the roles played by teachers in this context, remains lacking.

For these reasons, in the present study, we aim to examine how ECEC teachers can support children's mathematical learning, such as counting and measuring, reasoning, problem-solving and computational thinking, by interacting with children while they play with a coding toy.

Background

Learning mathematics through technology

The role of the teacher is crucial for children's mathematical learning (Niess, 2005, 2006). Technology has been used to facilitate teacher-child interaction (Mercer et al., 2019) and has been identified as a tool for teaching and learning (Alimisis, 2012). The mathematics education literature has emphasized the importance of the idea of mediation in relation to technologies (Shumway et al., 2021; Yeo, 2021). Technological tools or artefacts (for example, a coding toy) affect the process of interaction itself, so it is important to distinguish between the roles of the teacher and the artefact (Bussi & Mariotti, 2008). In fact, the artefact can modify children's behaviour in unexpected ways (Ladel & Kortenkamp, 2013).

The literature has focused on different theories that analyse the roles of teachers and artefacts in an educational environment, including "artefact-centred activity theory (ACAT)" (Ladel & Kortenkamp, 2013) and "semiotic mediation theory" (Bartolini Bussi, 2008). ACAT has been used to describe multitouch environments (Ladel & Kortenkamp, 2013), apps (Larkin et al., 2019) and coding toys (Welch et al., 2022), while semiotic mediation theory has been used to analyse children's mathematical learning while they play with coding toys in ECEC institutions, with a particular focus on the role of teachers in this context (Shumway et al., 2021).

For those reasons, we chose semiotic mediation theory as the theoretical framework for our article.

Based on the Vygotskian perspective, three elements are central to this theory: the artefact, signs (e.g., language and gestures) and the teacher's mediation (Bussi & Mariotti, 2008).

When children use an artefact (in this case, the coding toy), they start communicating using either their bodies or language, as does the teacher. What is important in this context is to establish connections among the children's play with the coding toy, their language and the gestures they make during this activity and their learning of mathematics. Children can accomplish this task through teacher mediation (Shumway et al., 2021). During mediation, the teacher prepares the activity and uses the coding toy as a means of mediation to encourage the children to learn the corresponding mathematical contents (Bartolini Bussi, 2008).

The teacher as a cultural mediator

According to this framework, the role of the artifact is to function as a channel for communication between the teacher and the children based on shared language and gestures. The social use of the coding toy enhances the children's and teachers' shared language and gestures. Teachers' mediation can then guide the children to learn mathematical content (Bussi & Mariotti, 2008). This mediation can be described in terms of two important aspects: first, the teacher orchestrates (Trouche, 2003) a playing activity with the coding toy and subsequently mediates the children's language and gestures to guide them to learn mathematics (Arzarello & Bussi, 1998).

Children's mathematical learning when playing with coding toys

When examining the ways in which teachers mediate different dimensions of children's learning of mathematics, it is beneficial to establish a framework for the content of the mathematics curriculum at an early age. The content of mathematical knowledge can be represented according to different classifications, including that presented by Bishop (1988), who considered mathematics to be a cultural product. We decided to refer to the adaptation of this classification to the ECEC framework presented by Solem and Reikerås (2001; 2017). This classification divides mathematics into six activities: counting, locating, measuring, designing, playing and explaining.

Young children use all these activities in their everyday lives (Solem & Reikerås, 2017) as well as when they play with coding toys (Granone

& Reikerås, 2021). However, the literature has mostly emphasised the use of coding toys as an important approach to the stimulation of problem-solving and structural thinking, which are parts of the activity of explaining (Çiftci & Bildiren, 2020; Wing, 2006). Polya (1971) defined problem-solving in terms of four sequential steps: an input phase, during which a problem is defined and understood; a processing phase, during which alternatives are evaluated and one is selected as the solution; an output phase that includes the implementation of the solution; and a review phase, during which the solution is evaluated and modifications are made if necessary. Another form of structural thinking is computational thinking (Wing, 2006). This way of thinking has been introduced in the context of ECEC education to connect problem-solving with technology, but no clear definition of this term has yet been provided. The literature has described this competence as a way of thinking about finding solutions based on two important components, i.e. abstraction and decomposition (Selby & Woollard, 2013).

Bishop's mathematical activity of *playing* occupies a special position in relation to preschool children. For children in this age group, play is essential to their wellbeing and learning (Pellegrini et al., 2007), and close relations have been found between young children's play skills and their mathematical learning (Reikerås, 2020). Scholars have expressed several opinions regarding what play is and should be in an educational context (Fleer, 2014; Samuelsson & Carlsson, 2008; Sutton-Smith, 2009). In Norwegian ECEC, the setting of the current study, children's free play is central and highly valued, and playful approaches permeate all pedagogical work with children. The national curriculum presents play as a need on the part of children and attributes to it intrinsic value (Kunnskapsdepartementet, 2017). The question of when children's play is mathematical has been discussed (Helenius et al., 2016). Playing has even been linked to the task of posing and solving problems in the context of Bishop's exploration of "what if" scenarios.

The present study

In the present study, the teacher supports children's play by using a coding toy that they can programme collaboratively by giving logical messages to the robot intuitively through direct interaction. The robot, which is called Kubo, can be programmed by linking puzzle tiles with arrows without the use of screens (for a more detailed description, see Bertel et al., 2019). As an artefact, the robot allows the children to increase their semiotic activity by using signs such as language and gestures (Bussi & Mariotti, 2008). Through its structure, Kubo offers many possible insights into mathematics in a way that is intuitive for children and easy for them to approach. This accessibility allows children to produce situated signs while playing with Kubo, and based on these signs (language and gestures), the teacher can support the children's mathematical development.

Research question

Against backdrop, we pose the following research question:

How can teachers support children's mathematical learning through the interactions that occur while they play with a coding toy?

Methodology

Participants

One ECEC teacher participated in the study alongside four children between three and five years old who were drawn from the same ECEC institution: Adam (aged 4.5 years), Marie (aged 3), Sara (aged 4) and Thora (aged 5). Conducting research with children demands special ethical considerations (Fine & Sandstrom, 1988). Informed consent was obtained from the teacher, the parents and the children themselves. The teacher was already familiar with the children and was therefore responsible for explaining the study to them in a way that they could understand. The children were informed that they could tell the teacher or use other ways to express to the teacher that they did not want to be observed at any time during the project. The children's names have been changed in this paper to comply with the ethical guidelines of the Norwegian Social Science Data Services, which gave permission to conduct the project. The data were stored on a secure server, and only the project leader had access to this information.

The ECEC institution in question was chosen because of its interest in increasing teachers' competence with regard to technology, in particular with respect to coding toys. The ECEC institution's educational strategy was inspired by the Reggio Emilia approach; as a result, a key aspect of this strategy was to encourage the children to continue asking questions, thinking and theorising while studying the children's methods of seeking answers. The teacher did not receive instructions regarding how to introduce the activities with the robot or how to use this activity with children. None of the children had previous experience with Kubo.

Procedure

The children and their teacher were video-recorded while they engaged in play-based problem-solving activities with the robot. The activities were performed three hours per week over the course of a month, for a total of 12 hours.

The activities were always conducted in the same room in the ECEC institution to allow the children to work in a familiar environment. The video camera was located at a fixed point to allow the researchers to observe the children closely and to capture their dialogue, language and gestures. This information was important to enable us to conduct the multimodal analysis. The same teacher was always present during the activities; however, on two occasions, another teacher was also present. To enable the teacher to play an active role in interacting with the children, it was decided that he would not handle the camera or make any annotations. This approach resulted in poor video quality with regard to two activities, which were therefore not considered in the analysis. The transcript excerpts that are included in this article pertain to situations that occurred when only the principal teacher was present. These transcriptions were discussed with the teacher.

A phenomenological approach to data collection was used for this exploratory study. Phenomenological research is used to understand the meaning of specific experiences. Phenomenology describes the meanings of experiences that are obtained through case studies in a systematic manner (Lipkin, 1990). Using a qualitative approach, the researchers explore teaching based on detailed observations of small case studies. Due to the study's small-scale and exploratory nature, it is necessary to discuss its external validity. Video data facilitate a cyclical analytical process whose goal is the transformation of video images into research objects. The video data were observed and analysed and subsequently discussed by the researchers to obtain agreement regarding the results.

Analysis

A descriptive analysis of the video-recorded play was conducted using a multimodal approach. The multimodal approach views communication and representation as encompassing more than language, and it offers a new perspective according to which verbal and embodied resources interact to create meaning (Jewitt, 2013).

The multimodal approach is based on several theoretical assumptions. The first such assumption is that all modes have the potential to contribute equally to meaning, and language is not considered to be the most significant mode of communication (Norris, 2009). The second assumption is that all modes are shaped by their cultural, historical and social uses; therefore, each mode has a communicative function. The third assumption is that people choose how to connect these modes to express meanings (Ventola et al., 2004).

The following conventions, as presented by (Jefferson, 2004) and (Mondada, 2008), are reported in the transcription as a result of the multimodal approach:

(1.5)	silence expressed in seconds
:	sound elongation
[xxx]	square brackets mark the beginning and end of a turn that overlaps with a preceding turn
**	delimitation of the description of an action

In addition, through descriptions of gestures and the images, it was possible to describe the language and gestures used by the children and teachers during the activity.

Results and discussion

This section reports three transcriptions that will be analysed from the perspective of the theory of semiotic mediation.

Children's spatial learning is mediated by questions

The children had previously experimented with the coding toy, which can move on the arrows that are used to build a path on the cardboard map. Each child was given time to explore the "behaviour" of the robot when it was placed on each symbol (green arrow, orange arrow). Subsequently, the teacher helped the children develop an understanding of each symbol. The children decided to use three symbols: the green arrow (which allowed the robot to move forwards), the orange arrow (which allowed the robot to turn left) and the blue arrow (which allowed the robot to turn right).

At this point, the children build a path to reach the goal drawn on the cardboard map. They use only the green arrows. They come close to the edge of the carboard map.

Adam: We need to turn.

**Adam takes Kubo and rotates it. Then, he puts it back in its position. **

Teacher: Turn right or left?

Thora: This way. **Thora points in the right direction. **

**Thora places an orange arrow, which directs the robot to turn left, whereas she should have chosen a turn to the right (blue arrow). The orange arrow is set to the wrong position in relation to the rotation, so it is impossible to understand the fact that this choice is a mistake visually. **

**The children finish building the path and try out the solution with the robot. When the robot reaches the orange arrow, it turns in the wrong direction. **

Adam: Stupid robot!

**The children smile. They try again, but the same thing happens. **

**The children laugh once again, but now they look confused. **

Adam: Stupid robot!

Teacher: Should it turn right or left?

Everyone: Right!

Adam: Stupid robot!

Teacher: Could it be that you are making the robot behave stupidly? Maybe he needs some other information?

**Thora takes a blue arrow instead of the orange arrow and positions it in the correct direction. **

Teacher: Aha! Now something's happening. You change ... yes ... see what happens now.

**The robot completes the path. **

Teacher: Ye:s!

Thora: I changed it.

Teacher: What did you do?

Thora: I changed the turn sign because I knew what he should do.

Teacher: It was smart.

Figure 1 can be used to understand the roles played by the artefact and the teacher during this activity.

In the activity thus transcribed, it is possible to identify important information regarding both the teacher's orchestration and mediation and the children's mathematical learning. The teacher organises (or more specifically orchestrates) the activity, gives the robot to the children and defines a goal (i.e., to reach the target shown on the cardboard map). The teacher previously explained how to use the robot and the meaning of each element of the robot (which can also be called situated signs (Bartolini Bussi, 2008)). During their free play, the children use language and gestures to communicate (**Thora places an orange arrow, which directs the robot to turn left, whereas she should have chosen a turn to the right (blue arrow). The orange arrow is set to the wrong position in relation to the rotation, so it is impossible to understand the fact that this choice is a mistake visually. **). In this activity, the teacher decides to mediate

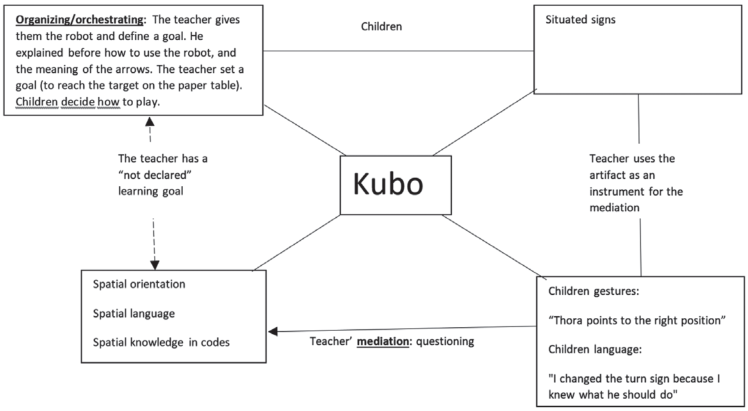

Figure 1. *The links among the different elements in the theory of semiotic mediation; this diagram was adapted from (Bussi & Mariotti, 2018) for this specific activity*

the process by asking questions, focusing the children's understanding on mathematics (Teacher: *Should it turn right or left?* Everyone: *Right!*).

The mathematical concepts and skills that the children encounter while engaging in these specific activities are related to space and, in particular, are as connected to Bishop's activity of "locating." More specifically, children's language and gestures can be classified into three areas of knowledge related to locating. These areas include spatial orientations (**Adam takes Kubo and rotates it. Then, he puts it back in its position**; **Thora points to the right direction** (figure 2)), spatial language (*I changed the turn sign because I knew what he should do*) and spatial knowledge in codes (**Thora takes a blue arrow instead of the orange arrow and positions it in the correct direction**). These areas have been classified in accordance with what has been presented in the literature (Shumway et al., 2021).

Figure 2. *"Thora points"*

In this example, the children are engaged in the task of solving a problem (to build a path leading from a starting point to a goal) and have the freedom to build the path in question. Mistakes play an important role in the learning process because every error leads the child to reflect and potentially improve his or her understanding (Ellis & Abbott, 2019). One reason for using activities that involve a coding toy is that this approach makes it easy for children to understand that a solution can be changed simply by modifying one or more commands, i.e., in this case, an arrow (**Thora takes a blue arrow instead of the orange arrow and positions it in the correct direction**). In this situation, the experience of uncertainty has no negative impact; instead, it plays an important role in content learning and interaction in the context of collaborative learning tasks (Granone & Reikerås, 2021). Mercer et al. (2019) highlighted the fact that coding toys can be used to facilitate dialogical interaction, as in this example when the teacher points to the robot to help the children analyse their mistake (*Could it be that you are making the robot behave stupidly? Maybe he needs some other information?*). This fact indicates that even if tools or artefacts (for example, a coding toy) can be used to support learning, it is the judgement of teachers that determines how these tools can be used in mathematics education (Davis & Miyake, 2018). In fact, the children understand they have made a mistake, but they are unable to analyse or identify that mistake by themselves (**The children laugh once again, but now they look confused.**). In the transcription presented above, the teacher guides the children in the process of understanding, allowing them to reflect on why the robot is behaving strangely. Moreover, when the situation is resolved, the teacher poses a question intended to help the children evaluate and analyse why the solution worked (*What did you do?*). This approach allows the children to evaluate their choices and consolidate their learning.

Children's problem-solving is mediated by a story as a playful context

At the beginning of the second activity, the teacher wants to help the children solve a problem that is similar, but not identical, to the previous problem. To engage the children, the teacher presents the challenge by using a story as a playful context.

Teacher: My name is Olga, and I am 48 years old. I have lost my house ... I cannot find my house ... Can you help me build a road to my house so that I can come home for Christmas ... So that I can come home to my children? Can you help me?

All: Yes!

Teacher: So good! (0.30)

Teacher: Close your eyes. I will count to three, and I will show you my house.

The teacher removes a curtain and shows the house. The house is built using a shoe, so the children laugh.

Teacher: Now, I need your help to build the road.

**The house is located far from where the children and the robot are located and can be reached simply by moving on the carpet. **

Adam: Olga is going home ...

Thora: We build the road here. **Thora points to the carpet. **

Adam: The robot ... O:lga ... Olga does not walk on the carpet. She goes here.

Adam points to the cardboard map.

**Nobody talks. **

**Sara takes the shoe and places it on the cardboard map. Adam and Thora indicate that they feel doubtful, but they say nothing. **

Adam: Olga is going home.

**Adam builds a road with the arrows on the cardboard map. **

**All the children try many times to change the path to enable the robot to reach the goal. After some time, they manage to do so. **

**The teacher takes the shoe and puts it back in place. **

Teacher: Olga is going home.

Adam: The robot ... Olga ... does not walk on the carpet. She goes here!

**Adam points to the cardboard map. **

Teacher: What are you doing now to help Olga?

Thora: What about the carpet?

Adam: The robot cannot handle the carpet.

Thora: However, it must be allowed to go home ...

Sara: I'm trying on the carpet.

**Thora takes the arrows and starts building the path on the carpet. All the others follow and place the arrows. They place the arrows one after the other, one for each child, as if they had decided on their roles without discussing them. There are not enough green arrows. **

Adam: Maybe the little one can walk a little bit too???

**All the children agree, which means that they do not consider the fact that the path for the robot is shorter than expected to be problematic. **

The mediational contents of this transcription are reported in figure 3.

In this transcription, the teacher creates a playful context, i.e., the story, to engage the children and to present a new problem that must be solved. Storytelling is an important approach in ECEC pedagogy, and studies have shown that it enhances children's literacy and communication

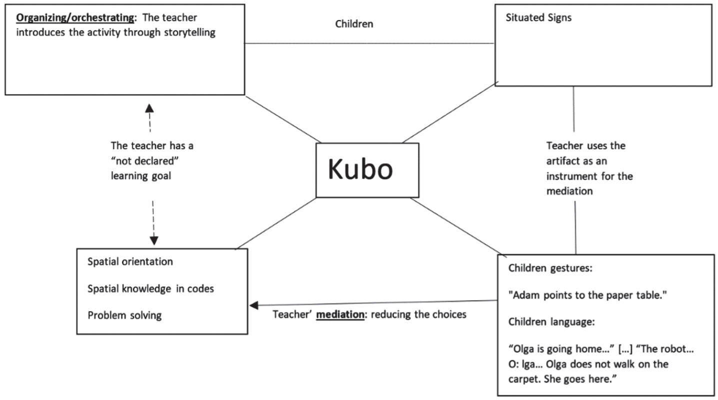

Figure 3. *The links among the different elements in the theory of semiotic mediation; this diagram was adapted from (Bussi & Mariotti, 2018) for this specific activity*

skills (Campbell & Hlusek, 2015; Isbell et al., 2004; Merjovaara et al., 2020) as well as their ability to think creatively (Phillips, 2000). The teacher uses the coding toy to cause the children to focus on the problem at hand and to help them use their thinking ability to solve that problem. This approach is in accordance with the literature, which has shown that technology can be identified as an artefact for teaching and learning (Alimisis, 2012). With regard to the adaptation of Bishop's (1988) classification to the context of ECEC, the transcription reports a dialogue among the children that can be related to the "explaining" activity (Solem & Reikerås, 2017). In fact, the children demonstrate the fact that they think (**Sara takes the shoe and places it on the cardboard map (figure 4). Adam and Thora indicate that they feel doubtful, but they say nothing**). They try to explain their thinking (Thora: *However, it must be allowed to go home* … Sara: *I'm trying on the carpet.*), which could have been facilitated if the teacher had guided the dialogue in a more explanatory manner. Accordingly, three out of the four phases of the problem-solving process (Polya, 1971; Schoenfeld, 2014) can be identified.

- an input phase, during which a problem is defined and an attempt is made to understand what is needed to solve the problem (*Olga is going home* ... [...] *The robot* … O:*lga* … *Olga does not walk on the carpet. She goes here.*);
- a processing phase, during which alternatives are generated and evaluated and a solution is selected (**All the children try many times to change the path to enable the robot to reach the goal.

After some time they manage to do so. [...] ** *The robot ... Olga ... does not walk on the carpet. She goes here!* [...] *I'm trying on the carpet.*); and

– an output phase, which includes planning for and implementing the solution (**Thora takes the arrows and starts building the road on the carpet. **).

The final phase, i.e., the review phase during which the solution is evaluated, is not clearly identifiable. The teacher does not sustain this evaluation aspect but focuses more closely on incentivising the children's creativity.

However, after the children have solved the problem on the cardboard map, they apply the same strategy on the carpet and eliminate unnecessary details (**All the children agree, which means that they do not consider the fact that the path for the robot is shorter than expected to be problematic.**). This identification of similarities is, according to (Selby & Woollard, 2013), an important step in computational thinking.

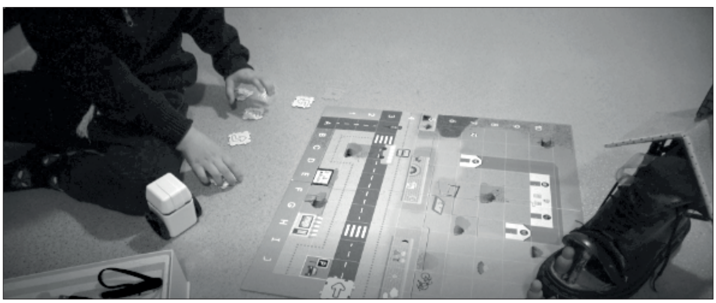

Figure 4. *Sara takes the shoe and places it on the cardboard map*

This transcription also highlights mathematical contents related to Bishop's activity of "locating." More specifically, those contents pertain to spatial knowledge in codes (**Adam builds a road with the arrows on the cardboard map**; **All the children try many times to change the path to enable the robot to reach the goal**).

However, the teacher orchestrates the activity through storytelling in the context of a playful situation. He challenges the children more by exhibiting certain actions (**The teacher takes the shoe and puts it back in place. **) than through a dialogical approach. The teacher and the children are then active in a nonverbal manner, which could be the reason that the children do not engage in an argumentative explanation of their decisions. The teacher asks an open-ended question (*What are you doing now to help* Olga?), thus helping the children use their freedom and creativity to solve the problem (*I'm trying on the carpet.* [...] *Maybe* *the little one can walk a little bit too*???). However, after this process, no dialogical exchange demonstrates the children's understanding of the events that occurred.

In the activity reported in this section, the teacher's mediation can be seen in his continual attempts to encourage the children's interest in the story. This approach allows the teacher to help the children focus, thereby supporting their learning by reducing the number of possible answers (Pentimonti & Justice, 2010).

Children's numerical learning is mediated by coparticipation

During a new activity in which the children are required to build a path on the cardboard map from a defined starting point to a goal, the teacher shifts the focus to the mathematical content and asks questions that require knowledge of length and numbers.

Teacher: How far did Olga have to go home?

Sara: A lot.

Marie: Like that. **Marie stretches her arms to demonstrate how far. **

**Thora sits down and begins to point with a finger at each arrow that has been used. Adam does the same. Adam and Thora count from opposing starting positions. **

Adam: 35.

Thora: 20!

Teacher: Oh, then there are different numbers coming out! So exciting! Can we count together? Maybe I'll get another number!

**The teacher slowly counts all the arrows and reaches 20. **

Teacher: I also got 20! So exciting! Why do you think that happened, Adam?

Adam: Some arrows went away ... **Adam speaks with an angry voice. **

Figure 5 presents a scheme of the different elements involved in the theory of semiotic mediation.

In this transcription, the teacher orchestrates the activity by highlighting to the children certain aspects connected to the "measuring" and the "counting" activities discussed by Bishop. Moreover, although open-ended questions could be used to enhance discussion of those topics, in this context, the teacher opts for a closed-ended question (*How far did* Olga *have to go to come home*?), to which the children decide to reply with a quantitative answer that they express by spreading their arms (Marie: *Like that.* **Marie stretches her arms to demonstrate how far. **) or with numbers (**Thora sits down and begins to point with a finger at each arrow that has been used.**). In the cited example, the children

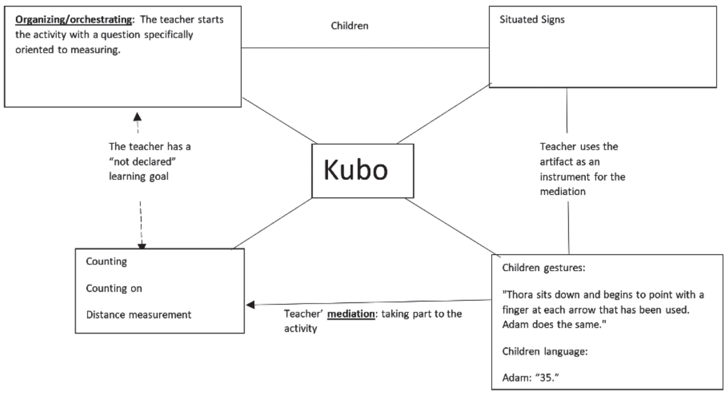

Figure 5. *The links among the different elements in the theory of semiotic mediation; this diagram was adapted from (Bussi & Mariotti, 2018) for this specific activity*

demonstrate their competence mostly in nonverbal ways. In fact, two children use their counting competencies to obtain a result. First, they must know the number sequence, following which they must count one object at a time by pointing at each arrow. Both Adam and Thora show that they know that the counting sequence should be said while pointing to the objects being counted (**Thora sits down and begins to point with a finger at each arrow that has been used. Adam does the same.**). It seems that Thora uses a 1-1 pairing approach and stops at 20, which is the correct answer. Adam does not count with the necessary precision. We cannot determine whether this failure is because he wants to finish first or because he has not mastered the 1-1 pairing approach; alternatively, perhaps he cannot recite the counting sequence correctly. Both children say the last number in the counting process. Whether they are aware of the possibility of using this approach to determine the quantity at hand is unclear. The teacher then encourages a dialogue both verbally and nonverbally to help the children understand the process. However, the teacher does not emphasise the fact that the last number said in the counting sequence answers the question of "how many." This clarification could have helped the children improve their understanding of cardinality. The teacher does not tell Adam directly that he is wrong; rather, he counts the arrows and obtains the same number as Thora. The teacher asks Adam why he found another number, and Adam becomes visibly frustrated (**Adams speaks with an angry voice.**). In this way, the teacher tries to reflect on the process of counting jointly with the children, but the result is that he blames Adam for his incorrect counting instead of focusing on what is important in counting. If he had done so, he would have supported Adam and the rest of the children. This example is in line with other research that has highlighted the importance of teacher sensitivity in interactions with children (Rimm-Kaufman et al., 2002). The same lack of support is visible when Marie tries to answer the question using her competence in the "measuring" activity. She cannot verbally explain what she means, but she uses her body to express the answer. In the activity reported in this section, the teacher's mediation can be seen in his decision to participate in the activity himself. It remains unclear, however, whether the teacher has achieved the goal of involving all the children present in the activity.

The data analysis has indicated that both the teacher's organisation (including the orchestration previously mentioned) and mediation are relevant to children's mathematical learning.

A synthesis of the results drown from the three transcriptions can be found in table 1.

Conclusion

In this study, we examined how a teacher can support children's mathematics learning while engaging in joint play with a coding toy. Our findings show that when coding toys are used in a playful situation, as in the case of this research, they can be employed as artefacts to teach and learn different aspects of mathematics, such as counting, measuring, and explaining. When playing with the coding toy, structured thinking is included as a problem-solving approach. Our study highlights the importance of the manner in which the teacher decides to orchestrate the activity, whether by giving the children instructions and goals or merely introducing the activity through storytelling. The role of the coding toy (artefact) is also central to teachers' ability to support the children's learning because it can shape children's language and gestures in accordance with its structure. The final important aspect of this research is related to teacher mediation. Questions, coparticipation or reductions in choices are only some examples of the various potential ways of supporting children's learning (Pentimonti & Justice, 2010). Although this case study faces certain limitations because of the small number of participants, it can raise interest in the need to support ECEC teachers' awareness of the power of orchestrating and mediating children's learning in the context of playing with coding toys. An important opportunity for future research could be to investigate whether the results would remain the same if the participating teacher receives guidance beforehand. Research on a wider scale is recommended to deepen our understanding of this topic.

Table 1. *Schematic synthesis of the results of the data analysis*

Bishop's activity		Transcription 1	Transcription 2	Transcription 3
Mathematical signs				
Locating	Spatial orientation	"Adam takes Kubo and rotates it. Then, he puts it back in its position" "Thora points to the right direction"	"Thora points to the carpet" "Adam points to the carboard map" "Oline takes the shoe and places it on the carboard map"	
Locating	Spatial language	<<We need to turn>> <<This way>> <<I changed the turn sign because I knew what he should do>>	<<We build the road here>> <<She (Olga) goes here>>	
Locating	Spatial knowledge in codes	"Thora puts an orange arrow (on the path)" "Thora takes a blue arrow instead of the orange arrow and positions it in the correct direction"	"Adam builds a road with the arrows on the carboard map" "All the children try many times to change the path to enable the robot to reach the goal" "Thora takes the arrows and starts building the path on the carpet. [...] They place the arrows one after the other"	
Counting	Counting			"Adam counts a little too fast. Adam and Thora count from opposing starting positions. Adam (says): <<35>>."
Counting	Counting on			"Thora sits down and begins to point with a finger at each arrow that has been used. Adam does the same."
Counting	Distance measurement			"(Marie says) <<Like that>>. Marie stretches her arms to demonstrate how far."
Explaining	Problem-solving		"input phase," during which a problem is defined and an attempt is made to understand what is needed to solve the problem (<<Olga is going home... [...] The robot... O:lga... Olga does not walk on the carpet. She goes here.>>); "processing phase," during which alternatives are generated and evaluated and a solution is selected ("All the children try many times to change the path to enable the robot to reach the goal. After some time, they manage to do so. [...] <<The robot... Olga... does not walk on the carpet. She goes here! [...] I'm trying on the carpet.>>); and "an output phase," which includes planning for and implementing the solution ("Thora takes the arrows and starts building the road on the carpet."). The final phase, i.e., the review phase during which the solution is evaluated, is not clearly identifiable.	
Teacher's mediation				
	Organising/orchestrating/activity with artefact	The teacher gives the children the robot and defines a goal. He previously explained how to use the robot and the meaning of the arrows. The teacher sets a goal (to reach the target on the carboard map). The children decide how to play.	<<My name is Olga, and I am 48 years old. I have lost my house... I cannot find my house.... Can you help me build a road to my house so that I can come home for Christmas... So that I can come home to my children? Can you help me?>> <<Now, I need your help to build the road>>. <<What are you doing now to help Olga?>>	"During a new activity in which the children are required to build a path on the carboard map from a defined starting point to a goal, the teacher decides to use dialogue and questions again. This time, he asks questions that require knowledge of length and numbers." Teacher: <<How far did Olga have to go to come home?>>
	Collective production of signs	The teacher mediates by asking questions and guides the children to transition from using the term "this way" or body language ("Adam takes Kubo and rotates it. Then, he puts it back in its position") to using more specific terms (right, left). Only two out of four children are participating actively (they have not yet reached a collective level of participation).	"Thora takes the arrows and starts building the path on the carpet. All the others follow and place the arrows. They place the arrows one after the other, one for each child, as if they had decided on their roles without discussing them. There are not enough green arrows." Adam: <<Maybe the little one can walk a little bit too???>> "All the children agree, which means that they do not consider the fact that the path for the robot is shorter than expected to be problematic." The teacher's mediation is based on telling the story again and again to reduce the choices involved in answering the questions.	Teacher: <<Oh, then there are different numbers coming out! So exciting! Can we count together? Maybe I'll get another number!>> The teacher tries to involve the children and guides them to understand the numbers, participating in the activity in his own right.

References

Alimisis, D. (2012). Robotics in education & education in robotics: shifting focus from technology to pedagogy. In D. Obdrzálek (Ed.), *Proceedings of the 3rd international conference on robotics in education* (pp. 7–14). Charles University in Prague.

Arzarello, F. & Bussi, M. G. B. (1998). Italian trends in research in mathematical education: a national case study from an international perspective. In A. Sierpinska & J. Kilpatrick (Eds.), *Mathematics education as a research domain: a search for identity* (pp. 243–262). Springer.

Bartolini Bussi, M. (2008). *Matematica: i numeri e lo spazio* [Mathematics: Numbers and space]. Junior.

Bussi, M. B. & Mariotti, M. A. (2008). Semiotic mediation in the mathematics classroom: artifacts and signs after a Vygotskian perspective. In L. D. English & D. Kirshner (Ed.), *Handbook of international research in mathematics education*, (pp. 746–783). Routledge

Bertel, L. B., Brooks, E. & Dau, S. (2019). Robot-supported inclusion and learning:: a case study on the KUBO robot in early childhood education. *Technology and Disability*, 31 (1), 22–23.

Bishop, A. J. (1988). Mathematics education in its cultural context. *Educational studies in mathematics*, 19 (2), 179–191.

Campbell, T. & Hlusek, M. (2015). Storytelling for fluency and flair: a performance-based approach. *The Reading Teacher*, 69 (2), 157–161.

Çiftci, S. & Bildiren, A. (2020). The effect of coding courses on the cognitive abilities and problem-solving skills of preschool children. *Computer Science Education*, 30 (1), 3–21.

Clarke-Midura, J., Kozlowski, J. S., Shumway, J. F. & Lee, V. R. (2021). How young children engage in and shift between reference frames when playing with coding toys. *International Journal of Child-Computer Interaction*, 28, 100250.

Davis, E. A. & Miyake, N. (2018). Explorations of scaffolding in complex classroom systems. *Journal of the learning sciences*, 13, 265–272.

Edwards, S., Mantilla, A., Grieshaber, S., Nuttall, J. & Wood, E. (2020). Converged play characteristics for early childhood education: multi-modal, global-local, and traditional-digital. *Oxford Review of Education*, 46 (5), 1–24.

Ellis, P. & Abbott, J. (2019). Learning from mistakes I: why it is important. *Journal of Kidney Care*, 4 (4), 225–227.

Fine, G. A. & Sandstrom, K. L. (1988). *Knowing children: participant observation with minors*. SAGE.

Fleer, M. (2019). Digitally amplified practices: beyond binaries and towards a profile of multiple digital coadjuvants. *Mind, Culture, and Activity*, 26 (3), 207–220.

Fleer, M. (2014). *Theorising play in the early years*. Cambridge University Press.

Granone, F. & Reikerås, E. K. L. (2021). Preschoolers learning by playing with technology. In O. M. Alegre de la Rosa, L. M. Angulo & A. Giambrone (Eds.) *Education in Childhood* (pp. 121–133). IntechOpen.

Greig, A. D., Taylor, M. J. & MacKay, T. (2007). *Doing research with children*. Sage.

Helenius, O., Johansson, M. L., Lange, T., Meaney, T., Riesbeck, E. & Wernberg, A. (2016). When is young children's play mathematical? In T. Meaney, O. Helenius, M. Johansson, T. Lange & A. Wernberg (Eds.), *Mathematics education in the early years* (pp. 139–156). Springer.

Isbell, R., Sobol, J., Lindauer, L. & Lowrance, A. (2004). The effects of storytelling and story reading on the oral language complexity and story comprehension of young children. *Early childhood education journal*, 32 (3), 157–163.

Jefferson G. (2004). Glossary of transcript symbols with an introduction. In Lerner G. H. (Eds.), *Conversation analysis: studies from the first generation* (pp. 13–31). John Benjamins.

Jewitt, C. (2013). Multimodal methods for researching digital technologies. In S. Price, C. Jewitt & B. Brown (Eds.), *The SAGE handbook of digital technology research* (pp. 250–265). SAGE.

Kewalramani, S., Palaiologou, I., Arnott, L. & Dardanou, M. (2020). The integration of the internet of toys in early childhood education: a platform for multi-layered interactions. *European Early Childhood Education Research Journal*, 28 (2), 197–213.

Kunnskapsdepartementet (2017). *Rammeplan for barnehagen: forskrift om rammeplan for barnehagens innhold og oppgaver*. Udir.

Ladel, S. & Kortenkamp, U. (2013). An activity-theoretic approach to multi-touch tools in early maths learning. *The International Journal for Technology in Mathematics Education*, 20 (1), 3–8.

Larkin, K., Kortenkamp, U., Ladel, S. & Etzold, H. (2019). Using the ACAT framework to evaluate the design of two geometry apps: an exploratory study. *Digital Experiences in Mathematics Education*, 5 (1), 59–92

Lipkin, S. (1990). Technology as ontology: a phenomenological approach to video image resolution. *Quarterly Review of Film and Video*, 12 (3), 93–98.

Mercer, N., Hennessy, S. & Warwick, P. (2019). Dialogue, thinking together and digital technology in the classroom: some educational implications of a continuing line of inquiry. *International Journal of Educational Research*, 97, 187–199.

Merjovaara, O., Nousiainen, T., Turja, L. & Isotalo, S. (2020). Digital stories with children: examining digital storytelling as a pedagogical process in ECEC. *Journal of Early Childhood Education Research*, 9, 1–26.

Mondada, L. (2008, September). Using video for a sequential and multimodal analysis of social interaction: videotaping institutional telephone calls. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, 9 (3).

Mowafi, Y., Abumuhfouz, I. & Redifer, J. (2019). A play-based interactive learning approach for fostering counting and numbers learning skills for early childhood education using QR codes mobile technologies. In I. Awan, M. Younas, P. Unal & M. Aleksy (Eds.), *Mobile web and intelligent information systems* (pp. 16–26). Springer.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: developing a technology pedagogical content knowledge. *Teaching and teacher education*, 21 (5), 509–523.

Niess, M. L. (2006). Guest editorial: preparing teachers to teach mathematics with technology. *Contemporary issues in technology and teacher education*, 6 (2), 195–203.

Norris, S. (2009). Modal density and modal configurations: multimodal actions. In C. Jewitt (Ed.), *The Routledge handbook of multimodal analysis* (pp. 78–90). Routledge.

Palmér, H. (2017). Programming in preschool – with a focus on learning mathematics. *International Research in Early Childhood Education*, 8 (1), 75–87.

Pellegrini, A. D., Dupuis, D. & Smith, P. K. (2007). Play in evolution and development. *Developmental Review*, 27 (2), 261–276. doi: 10.1016/j.dr.2006.09.001

Pentimonti, J. M. & Justice, L. M. (2010). Teachers' use of scaffolding strategies during read alouds in the preschool classroom. *Early childhood education journal*, 37 (4), 241–248.

Phillips, L. (2000). Storytelling: the seeds of children's creativity. *Australasian Journal of Early Childhood*, 25 (3), 1–5.

Plowman, L., Stephen, C. & McPake, J. (2010). Supporting young children's learning with technology at home and in preschool. *Research Papers in Education*, 25 (1), 93–113.

Polya, G. (1971). *How to solve it: a new aspect of mathematical method*. Princeton University Press.

Pramling, N., Wallerstedt, C., Lagerlöf, P., Björklund, C., Kultti, A. et al. (2019). *Play-responsive teaching in early childhood education*. Springer.

Pramling Samuelsson, I. & Johansson, E. (2006). Play and learning – inseparable dimensions in preschool practice. *Early Child Development and Care*, 176 (1), 47–65.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E. et al. (2004). A scaffolding design framework for software to support science inquiry. *The journal of the learning sciences*, 13 (3), 337–386.

Reiser, B. J. (2004). Scaffolding complex learning: the mechanisms of structuring and problematizing student work. *The Journal of the Learning sciences*, 13 (3), 273–304.

Reikerås, E. K. L. (2020). Relations between play skills and mathematical skills in toddlers. *ZDM*, 52(4), 703–716. doi: 10.1007/s11858-020-01141-1

Rimm-Kaufman, S. E., Early, D. M., Cox, M. J., Saluja, G., Pianta, R. C. et al. (2002). Early behavioral attributes and teachers' sensitivity as predictors of competent behavior in the kindergarten classroom. *Journal of Applied Developmental Psychology*, 23 (4), 451–470.

Samuelsson, I. P. & Carlsson, M. A. (2008). The playing learning child: towards a pedagogy of early childhood. *Scandinavian Journal of Educational Research*, 52 (6), 623–641.

Schoenfeld, A. H. (2014). *Mathematical problem-solving*. Elsevier.

Selby, C. & Woollard, J. (2013). *Computational thinking: the developing definition*. Paper presented at the 18th annual conference on innovation and technology in computer science education, Canterbury.

Shumway, J. F., Welch, L. E., Kozlowski, J. S., Clarke-Midura, J. & Lee, V. R. (2021). Kindergarten students' mathematics knowledge at work: the mathematics for programming robot toys. *Mathematical Thinking and Learning*. doi: 10.1080/10986065.2021.1982666

Singer D. G., Golinkoff, R. M. & Hirsh-Pasek, K. (Eds.) (2006). *Play= Learning: how play motivates and enhances children's cognitive and social-emotional growth*. Oxford University Press.

Solem, I. H. & Reikerås, E. (2001). *Det matematiske barnet* [The mathematical child] (1. ed.). Caspar.

Solem, I. H. & Reikerås, E. (2017). *Det matematiske barnet* [The mathematical child] (3. ed.). Caspar.

Sutton-Smith, B. (2009). *The ambiguity of play*. Harvard University Press.

Trouche, L. (2005). Construction et conduite des instruments dans des apprentissages mathématiques: nécessité des orchestrations. *Recherches en Didactique des Mathématiques*, 25 (1), 91–138.

Turan, S. & Aydogdu, F. (2020). Effect of coding and robotic education on pre-school children's skills of scientific process. *Education and Information Technologies*, 25, 4353–4363.

Undheim, M. (2021). Children and teachers engaging together with digital technology in early childhood education and care institutions: a literature review. *European Early Childhood Education Research Journal*, 30 (3), 472–489.

Ventola, E., Charles, C. & Kaltenbacher, M. (Eds.) (2004). *Perspectives on multimodality*. John Benjamins.

Vogt, F., Hauser, B., Stebler, R., Rechsteiner, K. & Urech, C. (2018). Learning through play – pedagogy and learning outcomes in early childhood mathematics. *European Early Childhood Education Research Journal*, 26 (4), 589–603. doi: 10.1080/1350293X.2018.1487160

Wang, X. C., Choi, Y., Benson, K., Eggleston, C. & Weber, D. (2021). Teacher's role in fostering preschoolers' computational thinking: an exploratory case study. *Early Education and Development*, 32 (1), 26–48.

Welch, L. E., Shumway, J. F., Clarke-Midura, J. & Lee, V. R. (2022). Exploring measurement through coding: children's conceptions of a dynamic linear unit with robot coding toys. *Education Sciences*, 12 (2), 143.
Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49 (3), 33–35.
Yeo, S. (2021). Semiotic mediation through technology: the case of fraction reasoning. *The Mathematical Education*, 60 (1), 1–19.

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