Chapter

Preschoolers Learning by Playing with Technology

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Abstract

In an evolving world, where both adults and children continuously have to adapt to different and unexpected situations, the need to develop strong problem-solving skills from early years is evident. In addition, recent events such as COVID-19 that have led schools to close have highlighted the parent's role in supporting learning. Technology should be considered a useful tool for communication and learning, both in-home and in preschool. A possible approach to enhance problem-solving skills is to play with technological devices together. This chapter results from a series of considerations on playful programming-based home learning experiences with tactile elements for preschool children. The text presents a qualitative analysis of children's learning of problem-solving skills enhanced by this activity as well as mathematics and language. The children use the device as part of their free play. In the state of this play, the children in our examples show happiness and a form of flow that can remind of what is found in mindfulness. The findings are discussed in light of related theories on play and problem-solving. Some practical advice for teachers and parents on how to set theory into practice is included.

Keywords: problem-solving, play with technological devices, free play and flow, preschool children, mathematics, language, parents' and teachers' role

1. Introduction

Play can be considered a fundamental activity regarding emotional, social and cognitive development, and learning for preschool children [1]. Many studies [2] have shown that play should be considered a preferential channel for stimulating children's skills and competences. Samuelsson and Johansson [3] noted that play and learning are dimensions that stimulate each other and should be viewed as an indivisible entirety [4].

Among several types of play, play with toys in which technologies are involved can be considered important as stimuli for 21st-century skills and increasingly important for future society [5]. Play with technology is found to be real play for children [6]. However, the relationship between child–child and child-adult care has to be sufficiently stimulated [7].

Recent studies show that introducing the concept of computational learning (understood as the research area that studies the design of machine learning algorithms to determine what sorts of problems are "learnable" [8]) already in preschool age allows children to develop different ways of thinking about problems and solutions. This approach stimulates the understanding of spatial concepts, reasoning skills and, above all, problem-solving skills [9].

The examples in this chapter are structured around the results of a qualitative study conducted for two months in the home environment during the lockdown that followed the COVID-19 pandemic. A descriptive analysis of video-recorded play situations between Magnus (five years and nine months) and Harald (four years and two months) was conducted using a multimodal approach. As a result, we present ideas that can be performed to enhance important skills for preschool children (problem-solving ability, nonverbal communication, linguistic ability, and self-confidence) by stimulating computational thinking with a playful programming-based toy. The robot used can be programmed by puzzling tiles together with arrows (for a more detailed description, see [10]).

2. Play and learning in preschool age

2.1 "The robot doesn't understand anything!": an example of how to help children understand and develop computational thinking

Harald plays with a programming-based robot with tactile elements. The toy is composed of a series of tactile blocks consisting of arrows that indicate directions. The robot moves on the path by reading the commands as it passes over these blocks. Harald builds a path (**Figure 1**). He then puts the robot at the starting point. The arrows are not connected well, and the robot stops. When Harald places the robot on the orange arrow instead of on the green arrow, the robot rotates, losing the direction of the path. Harald looks annoyed. Harald tries again, but the robot does the same. Harald sits in silence. He then builds a new path with just green arrows (forward direction). Harald seems satisfied because the robot follows the path (**Figure 2**).

In this example, the children develop thinking skills by playing with tactile arrows to build a path for the robot (programming/coding). Such thinking skills support learning and understanding and are often called computational thinking skills [11].

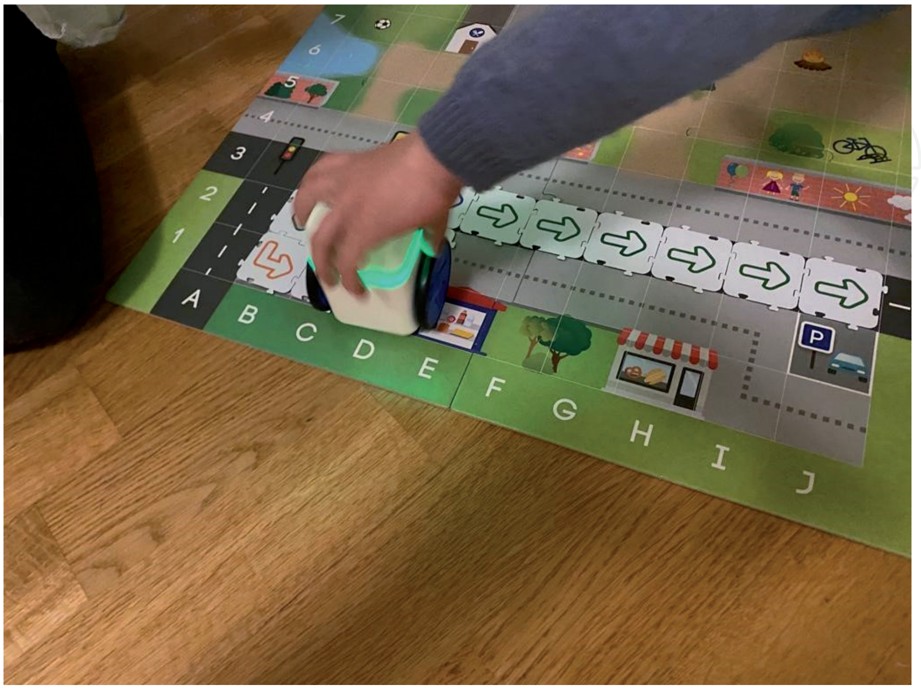

Figure 1.
Harald builds a path.

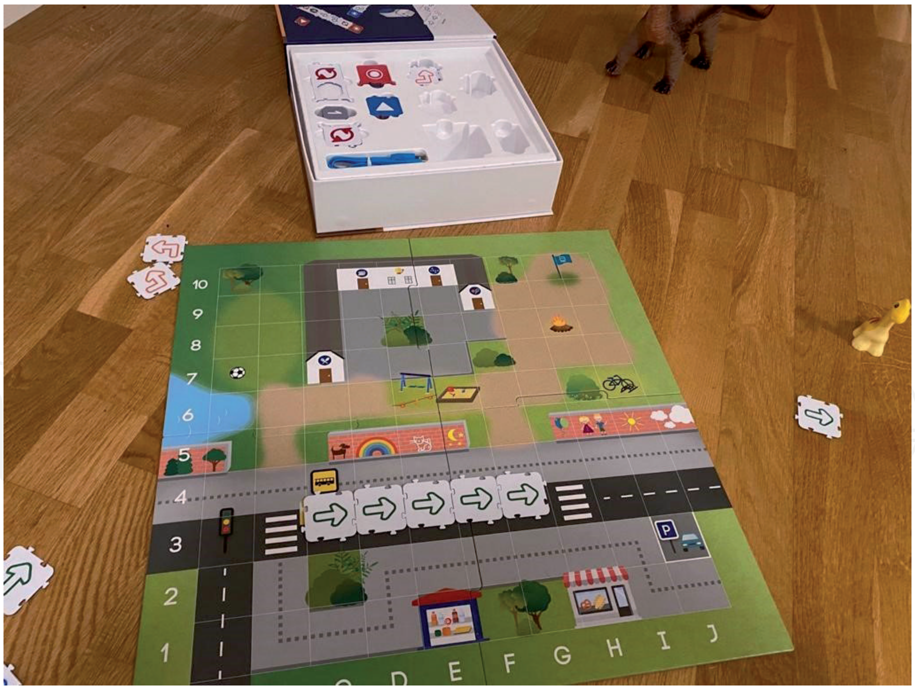

Figure 2.
Harald builds a new path with just green arrows.

The definition comes from Wing ([12], p.1):

"… the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent".

The development of operational thinking is not only applied in computer programming but can also be used in mathematics to enhance children's logical concepts, problem-solving skills, and deduction ability [13], as seen in Harald's play.

Selby and Woolard [14] identified five main themes that define computational thinking processes. The first is defined as the ability to think algorithmically, and it is considered the starting point for the whole process, which means identifying a way of getting to a solution through a clear definition of the steps and thinking in terms of sequences and rules. The second is described as the ability to think in terms of decomposition, which is clearly important. This step means that a way of thinking about artefacts in terms of their component parts has to be enhanced. The third can be described as the ability to think in generalisations identifying and making use of patterns. It is a method of quickly solving new problems based on previous solutions to problems and building on prior experience based on an analogical approach. The fourth is called the ability to think in abstractions, choosing good representations, which indicates the process of making an artefact more understandable, for example, reducing complexity by removing unnecessary detail. The fifth is the ability to think in terms of evaluation, which identifies a process of ensuring that a solution is good, for example, assessing whether an artefact does the right thing.

In Harald's play, it is possible to identify 4 out of 5 themes that are considered computational thinking.

Harald defines the steps (he wants to let the robot go from one point to another, and he builds the path). He thinks in terms of decomposition (he chooses the arrows). He thinks in abstraction (by reducing the path's complexity when the robot shows problems). Finally, he thinks in terms of evaluation (he is satisfied when the robot understands).

However, this example shows that Harald seems frustrated when the robot does not respond, as Harald has decided. Such play can be sustained by the mediation of teachers, parents, other adults or children by helping the child start from a working solution to implement a more complex solution (reasoning based on the concept of analogy), which is particularly important [15, 16].

2.2 "I think that you should try again": how the adult enriches play

The adult is more present in the next example and uses a problem-based learning design [17], helping the child set his own learning goals through a problem scene.

Adult: "Can you now build a more complicated path? I think that you should try again". Harald is not so sure. He sits in silence, but after a while, he agrees. He destroys the path, and he builds a new path, which in any case includes a blue arrow. Harald traces the path with fingers before and after letting the robot go. It works. Harald is extremely satisfied (**Figure 3**).

In accordance with a problem-based learning design, the child explores the learning solution by himself. Usually, the child should report his own learning conclusions, but here he communicates his results with nonverbal language (he clearly shows his satisfaction). In this example, however, a child's reflection about the results is still missing.

The play that Harald started was initiated by him. This is usually called free play, and it has been associated with a state of flow [18]. This is a type of play where children are allowed to play without any direct interference from adults, such as teachers or parents [17]. Free play is often said to be the opposite of guided play, where the adult sets the rules and initiates play [19].

Synodi [19] also mentions a third type of play: mutually directed play. In this type of play, adults become involved in children's free play in a non-disruptive manner [20], as the adult does in Harald's play. As a co-player, the adult enriches the play, and the teacher thus scaffolds the children's play and learning [18, 19].

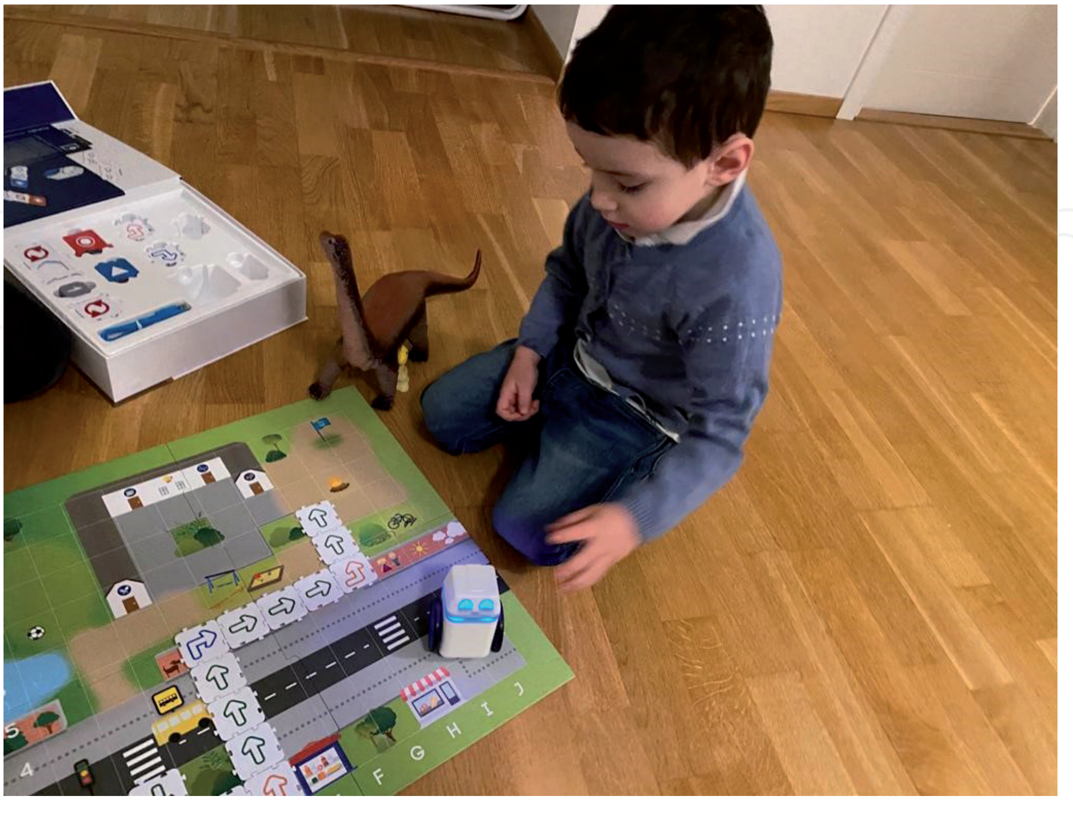

Figure 3.
Harald builds a more complicated path.

2.3 "Do I have to put an arrow here?": How to use coding to enhance mathematics knowledge and problem-solving skills

As described in the examples above, coding activities are not only important to sustain fundamental skills for computer science but also for developing the children's critical and creative thinking skills [21]. Studies indicate that students also learn a range of mathematical concepts during the process of learning how to code [22], especially if they can be facilitated in learning by using visual elements [23].

Magnus and Harald play with a robot. They decide that the robot should move to reach a dinosaur.

Magnus: "I arrange the arrows forward, on that side and that side" (moving hands to show that he means right and left, without giving a comprehensible explanation in any case). Magnus puts a sequence of arrows on the carpet.

Adult: "Can you tell me if the robot should go right or left?"

Magnus: "Do I have to put an arrow here, on this side?"

Adult: "What does this direction mean?"

Harald intervenes by placing an arrow indicating the correct left turn (orange arrow) instead of the right turn (blue arrow) that Magnus was trying to place.

Magnus then sets the arrow that he had in his hand to continue the path in the correct direction. They continue working together and then they verify the path with the robot (**Figure 4**).

Magnus: "Can we prepare a new one? Can we do it this way?" (Magnus traces a new road pointing with a finger).

In this example, children identify the problem, they decide where to go and place a dinosaur at this goal. Subsequently choose the arrows because they understand what they need to do. They then study, choose and try a solution. At the end, they define a new problem ("Can we prepare a new one?"). They build and try, but they need the adult's help to review and reflect on the meaning of their actions and decisions. Following Polya's definition of the problem-solving process, this can be considered as built with 4 sequential steps [24]. The first step is an input phase, in which a problem is defined, and an attempt is made to understand what is needed to solve it. The second step can be identified as a processing phase, in which alternatives are generated and evaluated, and a solution is selected. The third is an output phase that includes planning for and implementing the solution. The fourth is called

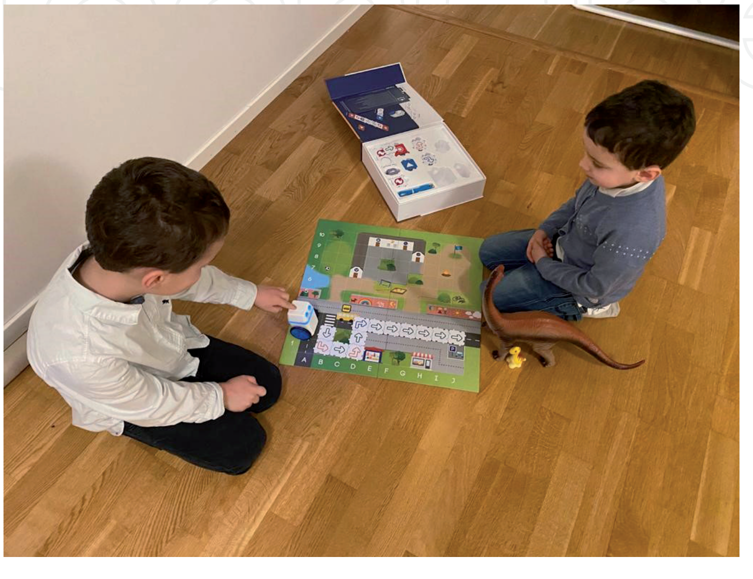

Figure 4.
Magnus and Harald decide that the robot should move to reach a dinosaur.

a review phase, in which the solution is evaluated, and modifications are made if necessary.

The literature has highlighted tendencies towards collaboration and problem-solving by using coding tools with preschool children [5]. In fact, Magnus and Harald explained how they think, both with and without verbal language. Problem-solving skills that the coding process solicits can enhance mathematical skills.

Research shows that children undergo extensive mathematics development over the first five years of life [25, 26]. There are many opportunities for teachers and parents to support their mathematical learning, using formal and informal situations as play-based activities or supporting children's free play [4, 27–30], as described in the last section.

When Magnus and Harald are involved in playful programming-based home learning experiences with tactile elements, they use mathematical skills. These skills are spatial orientation skills (to understand where the robot must go), measurement skills (how far the robot must travel to arrive at the point established as a finish line), and counting skills (how many arrows the child has to place in sequence to cover a certain distance). Understanding different dimensions in space is also stimulated, especially through the sense of touch, because the child experiences the different dimensions of the tactile elements (which can be considered almost two-dimensional) and the robot's dimensions (similar to a square-based prism).

In this example, Magnus and Harald struggle to find words to describe what happens to the robot, although they have well-developed linguistic skills.

The adult's approach is to then stimulate the verbal explanation to allow them to reflect on what has been done. Here, a game-based learning design is proposed [13]. Using this method, the adult asks Magnus and Harald to set up their own goals and to create ideas to achieve them. Games include many problem-solving characteristics because children must face an unknown outcome, multiple paths to a goal, and construction of a problem context to reach the goal by collaborative behaviour. A very useful learning aspect can be stimulated through the dialogue between adult and child or between child and peers. From a dialogue on what has been done to encouraging the explanation of robot orientation (be it verbal or nonverbal), the adult helps Magnus and Harald reflect on their actions (metacognition). Thus, the children can reinforce their understanding [31].

2.4 "The robot goes blablablabla": How to help children express themselves

While the robot moves, Harald hits the carpet, knocking the dinosaur away and causing the robot to go slightly off the road. Magnus places the dinosaur and robot again. The robot is placed on an orange arrow (indicating a right turn) instead of a green arrow (indicating forward). Instead of following the marked path, the robot turns to its right and then goes back on the path (**Figure 5**).

Magnus: "Nooooooooo".

Harald: (laughing): "Noooooooooo".

Adult: "Why is the robot doing this?"

Magnus(laughing) "Maybe because this goes this way." Magnus indicates the fact that the orange arrow indicates the right turn, which causes the turn, not the direction straight ahead.

Magnus(laughing): "But what does the robot do?"

Adult: "So what does the robot do sometimes?"

Magnus: "But that's because this … (pointing to the turning arrow) … this does so (pointing with the finger in the direction of the turn)."

The adult reproduces the same gestures done by Magnus. "What does it mean? What are you trying to say? Can you explain it? Try to analyse each step."

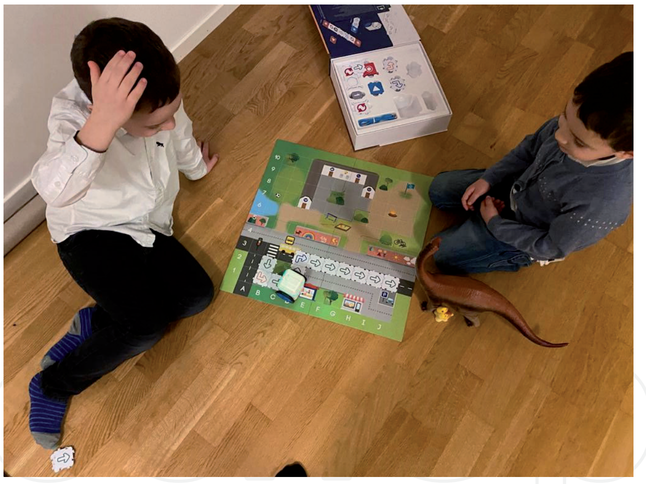

Figure 5.
Instead of following the marked path, the robot turns to its right and then goes back on the path.

Magnus: "The robot is on the orange arrow".
Adult: "Yes, and what happens?"
Magnus: "The robot goes wrong".
Adult: "Why?"
Magnus: "The robot turns".
Adult: "What does the orange arrow says?"
Magnus: "Turn".
Harald: "Turn" (he repeats thoughtfully).
Adult: "And what does the robot do?"
Magnus: "It turns. It turns? It turns! Therefore, it works!"
Harald: "Turn" (he repeats, thoughtfully).
Magnus: "I can explain you…".

In this example, Magnus and Harald make meaning beyond language by using speech, gesture, and gaze to be understood. This multimodal approach [32] deemphasizes the centrality of language and considers multiple "modes" of communication.

The collaborative interaction was mediated through spoken language, actions and artefacts, as Magnus, Harald, and the adult sat together on the floor with the robot and tactile arrows. The adult's behaviour was a mediational approach aimed at sustaining and bringing the activity to a successful conclusion. This sustained the children in their process of finding the knowledge required for effective expression of their thoughts [32].

Adopting an encouraging approach, the adult helps the children reduce the task to a series of achievable goals and describes each command instead of the whole path.

Inspired by the dinosaur that Magnus and Harald used in their play, the adult could have enriched the play relating the situation to a fantasy world where the dinosaur was a living creature. In this way, the children's imagination would be involved more strongly. Following the research, one of the most powerful tools for learning language could be storytelling [10, 13], for example, by using dinosaurs and robots.

2.5 "Do you find any problem?": how to help children understand that a mistake is just a sign that something needs to be changed for better learning

In the learning process, an important role is played by mistakes. Errors should be considered milestones in educational praxis because every time that a child is wrong, he can find the possibility to reflect, understand and learn [33]. However, this does not happen, and mistakes are often related to a sense of frustration caused by the impossibility of modifying a decision.

The programming approach instead shows that a solution can be changed just by modifying one or more commands. In this condition, the experience of uncertainty does not have a negative impact; instead, it plays an important role in content learning and interaction during collaborative learning tasks [34]. This interaction can occur between peers or between children and adults.

Adult: "Can the robot understand what you do? The robot does what you think or what you say with the arrows?"

Harald: "He reads the arrows".

Adult: "Can you follow the path with your finger? Do you find any problem?"

Harald points with his finger from the starting point and follows the path. When two arrows point in the same direction, he stops, uncertain about what to do (**Figure 6**).

Harald verifies with the robot that it is impossible to follow the path. The robot takes the wrong direction at the same point. Harald stops and thinks. After he destroys the path, he builds a new path, which in any case includes an orange arrow. Harald traces the path with fingers before and after with the robot. The robot completes the path. Harald is extremely satisfied.

The approach presented by the adult in this example is related to systematic computational learning theory [13]. In this method, the adult precisely formulates and addresses questions regarding the performance of different learning algorithms. This helps the child reflect on each command, identify the error and find a solution.

This consequence is a decrease in frustration and an increase in the sense of satisfaction when the goal is achieved, as shown in the example.

Figure 6.
Harald points with his finger from the starting point and follows the path.

Another reflection about errors and uncertainty leads to consideration. In some situations, creative problem solving may require intentional uncertainty generation to investigate new ideas, followed by uncertainty reduction during the process of identifying the best option. When the child is not playing alone but is involved in a group where effective collaborative brainstorming is needed, a strategy could be to sustain task uncertainty to increase the communication necessary to find a solution and reach the goal [35, 36].

This approach to error allows an increase in the joyful part of playing.

3. Conclusions

The play situations that Magnus and Harald experience are amazing and engaging, but they are also an opportunity to learn different skills, such as the understanding of mathematical concepts and problem-solving. In addition, children can enhance their verbal skills, while self-esteem and confidence are indirectly reinforced.

Play involves elements of joy, satisfaction and reward, excitement and pleasure, freedom and self-confidence [37]. When the child plays, he enters his own world and experiences happiness; this condition is defined as flow [38]. The child feels outside time and space, and his mind floats away without thinking about anything other than play. The child finds joy, excitement, and a driving force to master challenges. The "flow experience" helps the child feel confident, and in this way, he increases his own self-awareness [37, 39]. Early research showed that preschoolers engaged in exploration in settings where 'free-flow' play characterised practice [18]. In alignment with this aspect, our experiences presented in this chapter show that children who experience "free-flow" increase their self-esteem and discover the freedom to experiment with non-conventional solutions.

An important role is played by the adult, teacher, or parent. Adults have the important role of supporting children in their learning through a mediated learning approach, regardless of the type of teaching method they intend to use in presenting activities to children. This approach implies that adults do not provide predefined answers to children but support them in their process of research and construction of their own learning.

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