Children in movement towards STEAM: Coding and shapes at kindergarten

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CHILDREN IN MOVEMENT TOWARDS STEAM: CODING AND SHAPES AT KINDERGARTEN

Francesca Ferrara[1], Giulia Ferrari[1] and Ketty Savioli[2]

[1]*Università degli Studi di Torino,* [2]*I.C. Chieri III;*

Abstract

In this paper, we present a project that involved two classes of kindergarten children and their teachers in a teaching experiment focused on the development of spatial and computational thinking using a simple robot (Blue Bot). We focus on the design of activities, which also make use of playful movement experiences, with the aim of creating an inclusive environment in which children aged three to six can explore mathematically relevant ideas such as length, direction, and shape. We will discuss the initial insights coming from the teaching experiment on how children approached the length of straight paths.

Keywords: Bodily movement, coding, computational thinking, STEAM, spatial thinking.

FRAMING THE STUDY

There is a growing interest in mathematics learning in early childhood (e.g., Clements & Sarama, 2007), but the number of research studies focused on the use of digital tools in mathematics sessions for young children is still limited (Carlsen et al., 2016). Nevertheless, young generations are born in a digital world, and it is likely that pre-schoolers become familiar with digital devices before they are exposed to books (Hopkins et al., 2013). Balanskat and Engelhardt (2015) further highlight that many of today's students will be involved in future developments of technology, which is important for society. Programming skills, therefore, became more and more relevant for the 21st-century skills required for future citizens and came to be integrated into the curricula of many countries as they are related to skills like problem-solving, creativity, and logical thinking, with which learners need to be equipped in the digital world nowadays.

Schools have then increasingly integrated programming into other subjects, like mathematics, a concept that is not completely new as Papert (1980) already proposed to use programming in mathematics education, intending to provide different environments for the learning of mathematics and motivate students to engage with mathematics. Papert, for example, developed a Logo environment that required learners to program a computer to move a little turtle on the screen. Later, Benitti (2012) wrote a literature review in which he analysed the potential of robotics in schools and found that, in the examined studies, robots were useful to understand STEM concepts. Benitti and Spolaôr (2017) further underline that the potential use of robots within the mathematics classroom can be seen as a support tool. A recent review specifically investigates the use of programming in mathematics education for students aged 6 to 16 (Forsström & Kaufmann, 2018).

Concerned with mathematical cognition with very young children, several studies have been investigating early learning of number and number sense using multitouch applications (e.g., Sinclair et al., 2016; Ferrara & Savioli, 2018). In such a digital environment, for example, specific gestures are used to create and manipulate numbers, but children's perceptual and bodily engagement is enriched by auditory and visual responses to touch. The usage of simple robots, like Bee-Bots, was discussed in the field as a manner to foster the development of children's geometrical understanding and to create occasions for early steps into computational thinking through coding activities. Studies show the strength of this technology to work on spatial abilities at the end of kindergarten, with 5-year-old children (Sabena, 2015), and to work on definitions of simple geometric figures, for example, the rectangle and the square, in primary schools (Bartolini Bussi & Baccaglini-Frank, 2015). What we find intriguing about using this artefact within the mathematics classroom is the way that starting from playing it, children can move their very first steps into 3D explorations in space with their bodies, imitating the robot's movement or comparing their own movement with the robot's. This opens room for processes of understanding and communicating about movement, direction, and path of the robot, and their relationship with spatial thinking and shape in mathematics.

In this paper, we want to contribute to this line of research about robotics and mathematics with very young learners by presenting insights from a teaching experiment designed and carried out as part of the project "Children in Movement towards STEAM", whose target are children aged 3 to 6 and their families. The intervention aimed primarily at introducing kindergarten children to coding and mathematical thinking, as a tool to start *making sense* of the complexity and variety of experiences they live and as a first approach to computational thinking at school. We will focus on the structure and objectives of the activities and offer, through a brief classroom excerpt, some initial discussion on how preliminary activities involving children's bodily movements created the ground for further mathematical investigations into coding activities.

CHILDREN IN MOVEMENT TOWARDS STEAM

"Children in Movement towards STEAM" aims at engaging kindergarten children in laboratory activities about mathematics and robotics as an approach to the development of mathematical and computational thinking. The specific reference to STEAM (Science, Technology, Engineering, Art and Mathematics) helps to frame the project from a wider perspective, which takes into account the interdisciplinary nature of mathematics as a discipline that allows developing critical thinking and problem-solving, and argumentation skills in a variety of contexts. The project wants to nourish a vision of the cultural value of mathematical-scientific knowledge for learners to become aware citizens. Also, it makes room for creativity in the teaching and learning of mathematics, a dimension that is often neglected but is significant to engage in learners from an early age and to work on the relationships between mathematics and other sciences as well as art.

While mathematical digital competency (Geraniou & Jankvist, 2019)—the ability and awareness of using instruments in various contexts and engaging in mathematical discourses and solving mathematical problems with digital devices—is generally discussed for older students, it is also apparent that young children develop with extraordinary ease fascination for and mastery of digital devices. It is a matter of concern for educators that this pre-disposition is somehow directed, during the school years, towards a critical use of digital devices. This can be achieved through the design of mathematical activities that account for the playful engagement with the instrument while valuing the relationships with it as one that includes questioning and discovery in manners that are typical of the scientific process. Moreover, taking a multimodal approach to cognition (e.g., Ferrara, 2014), all the modalities along which a mathematical activity develops come to constitute the learning process. In line with this idea, a design principle to consider is to incorporate and value bodily, imaginative, and semiotic aspects into any activity.

Concerning tool use, we take as a reference the idea of mathematical instrument "as a material and semiotic device together with a set of embodied practices that enable the user to produce, transform, or elaborate on expressive forms (e.g., graphs, equations, diagrams, or mathematical talk) that are acknowledged within the culture of mathematics" (Nemirovsky et al., 2013, p. 376). This definition wants to embrace the complexity of learning to use a new tool and encompasses a non-dualistic approach to tool use, which values the minute interactions that come to constitute the experience of playing an instrument. The expression "playing an instrument" is purposely used by the authors to evoke musical instruments, for which the ability of playing is indiscernible from the fluency of using the instrument and some knowledge of music.

Nemirovsky and colleagues (2013) study how subjects interact with mathematical instruments in informal learning settings (museums) inside a semi-structured environment that is quite different from a kindergarten classroom. However, we see their perspective as appropriate to investigate tool use in our context. First, these researchers conceptualize tool use to the extent to which tools get incorporated into one's lived experience. This also means that one's investment in tool use emerges out of many aspects and that the tool (thoughts regarding it, sensations felt when using it, etc.) might permeate moments that are temporally far from the actual use. Secondly, this perspective allows us to move away from an instructional perspective on tool use, towards a vision of tools as occasions for meaningful encounters with mathematical concepts. In this direction, a second design principle that was crucial in the context of kindergarten activities is to use narrative as part of the teaching story, to engage children in discovery and reasoning and to raise their motivation.

After all, language and mathematics are the basis of computational thinking, which has a specific role in the National guidelines for the curriculum of the primary cycle (kindergarten to junior high school in Italy; Ministero dell'Istruzione, dell'Università e della Ricerca, 2017) in line with the curricula in other countries. Coding and computational thinking are associated with logical, analytic, and creative thinking because they allow for problem-solving by constructing procedures, establishing connections and planning strategies, and intervening every day in facing and solving problems. Regarding the mathematical content, the guidelines specifically highlight that since early childhood, children develop spatial reasoning, learn to describe the distance and location of objects in space in their own words, and discover geometrical concepts like those of direction and angle.

The project activities involved the kindergarten children using little robots (Blue Bots) to walk along open and closed paths (segment lines, L- or U-like lines, squares). The robots need to be programmed accordingly. While, in this manner, children learn coding and explore relations between the shape of the path and the corresponding code (as an approach to computational thinking), the aim is to stimulate an initial understanding of squared paths as shapes that satisfy certain mathematical properties. We can, for example, articulate on a square-like path saying that its sides must be formed by the same number of steps, and its turns (90° rotations) must occur in the same direction. Or describe it as the repetition of the same sequence (e.g., forward-forward-right turn) four times. These ways of seeing (and speaking of) the square allow for thinking of the shape in terms of spatial properties (e.g., side and angle equivalence). In addition, the activities implicate aspects of direction and orientation as well as of movement in space, introducing children to the capacity of reasoning on spatial relationships and the development of spatial thinking.

PARTICIPANTS AND METHOD

Three teachers from two different schools based in the surroundings of Torino (Italy) have been involved in the design of the project activities during the initial phases of work and have conducted a teaching experiment with their respective classes. The teaching experiment consists of 4 activities, each carried out in two 45-minute-sessions with a group of 12 children (half of the class), for a total of 9 sessions per group. The children in each group are 3 to 6 years old. A kit of six Blue Bots was available for each group in every school. Resources and materials have been designed to guide teachers' work in the classroom, but they do not have a fixed structure; rather, they serve choices by the teachers along the way. The activities have been refined and redesigned during the whole duration of the experiment, by considering the children's responses to specific tasks and associated difficulties in managing the group of students. In-between the sessions, the teachers were free to work on collateral activities that do not directly face the mathematical content but that complement it in some fashion. For example, in one of those activities, children were asked to produce drawings associated with bodily experiences focused on how we step during walking (something that anticipates later work on the way that the robots move when they must cover a certain distance).

The children's parents took part in a presentation of the project and its purposes, to raise awareness and interest towards the relevance of the teaching experiment and, at the same time, of mathematical and scientific knowledge as a thinking and problem-solving means that can help children to face the complexity of their experiences in the world. They also had a role later when asked to partake in a final, collective digital creation to be shared with the researchers and all the other families. Parents' involvement in the project is seen as a crucial point to sensitize families not only towards the value of the children's mathematical experiences but also towards the value of the relationship between parents and children concerning the learning dimension.

The authors of this paper participated in the conceptualization and design of the project (the third author is a primary school teacher with huge experience in curricula and design-based research activities). Two researchers (the first and second authors) were present during the intervention as active observers, one for each class. They could therefore interact with the teacher and the children, giving support to the teachers during the activities. The sessions were video recorded with a mobile camera, and all the written productions (mainly drawings) created by learners were collected. Weekly meetings between the researchers allowed to introduce variations in the implementation and refinements of the initial draft of the activities. After any activity, an individual interview with each teacher was also carried out to have information about the state of the art of the intervention and indications about its development. Some of the productions by the children, together with photos and short video pieces, were used to create an online Padlet board, weekly updated by the teachers and made accessible to all the families to share the flavour and some content of the activities with parents. In the following, we focus on the main ideas that characterized the creation of the activities. We will then discuss some insights coming from the teaching experiments.

THE TECHNOLOGY: BLUE BOT

Blue Bot is a simple bee-shaped robot (Figure 1). It can be moved by pressing a sequence of movement commands through orange buttons with arrows on the bee's back: forward, backward (about 15 centimetres), left, and right (90-degree turns). Pressing the green button "GO" will make the robot move accordingly to the sequence that has been programmed. A one-second pause button can be used. A delete button (showing an "X") allows learners to clear out their commands and start a new sequence from scratch.

Figure 1. Blue Bot (front and above view) and the buttons with the commands on its back

As Bartolini Bussi and Baccaglini-Frank (2015) point out, many significant processes that are typically mathematical or related to computer science emerge out of playing with this device: counting (the number of commands), measuring (the length of a step or the path, the total distance travelled by the robot), exploring space, constructing frames of reference, coordinating spatial perspectives, programming, planning, and debugging. The trajectories that can be walked by the robot are broken lines and possibly polygons with 90-degree-angles. For example, a square-trajectory with each side 2 steps long is walked when a sequence of forward-forward-right, repeated four times, is programmed. The device resembles the real little animal but has hybrid characteristics of a robotic creature: it makes sounds as it moves and stops. This helps the children develop an affective relationship with the tool and care about it and its peculiar behaviour.

OVERVIEW OF THE ACTIVITIES

The activities are learner-centred and engage the children through making, bodily actions, senses, movement, and diagramming to foster their participation and motivation in playing with mathematics. They often challenge children to work in groups and collectively to promote a vision of mathematics as an activity with socio-cultural value, in and outside of the classroom context. The children are also part of heterogeneous groups to foster collaboration between different age levels. During the teaching experiment, different modalities and contexts were alternated. We used a set of introductory activities focused on movement in between points of reference within a space of the school, flowers previously coloured by the children and placed on the floor. In such activities, the children initially explored free movements and then were asked to control or limit their manners of stepping from one flower to another, with tasks proposed by the teacher in a playful environment.

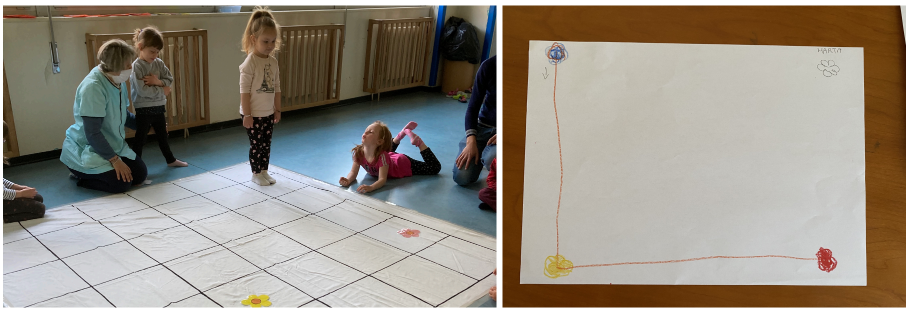

Figure 2. Activities involving body movements and drawings throughout the experiment

After this phase, the teacher removed all the flowers but two and led a collective discussion that focused on how one can move from one flower to the other. Great attention was given to understanding one own's way of moving and eventually the number of steps, and the children were encouraged to share their thoughts verbally or express them through a drawing (Figure 2). The device was introduced through a video prompt and a treasure hunt on site. The video, created for the children in Powtoon, presented a character, a little girl named Alice, who asked the children to help her to look for her special bee-friends because they were lost and hid in the school (Figure 3, left). This was done to create a narrative storyline that connected different moments of the experiment and of providing the children with an objective that guided their interactions with the device and introduced problems that the children had to solve. In the storyline, indeed, Alice was worried about the bees to be able to return home and engaged the children to understand and teach them how to move from one flower to another.

The Blue Bots were then investigated by the children regarding how they look and how they move. After this examination phase, the children shifted to observing the kind of movement of the robots and exploring the presence of buttons and their role in that. At this point, the children programmed the robots for the first time, to have them moving along straight segment lines of different lengths and started guessing about the number of necessary steps or commands.

Figure 3. A frame of the video introducing the treasure hunt; using arrows to describe movements

A general idea of the design was that of alternating moments in which the tool was present and in use and others in which it was only recalled, and body explorations in space were prevalent in the activity. Following the existing literature, a considerable amount of time was devoted to comparing the children's movement and that of the robot. This was done to 1) promote a multimodal approach to the activities and 2) to provide the children with initial insights into both ways of moving and a shared vocabulary in the classroom on how to describe directions, paths and orientation.

In the last part of the teaching experiment, arrows were used to codify the movements of both the bees and the children (Figure 3, right) through an ordered sequence of arrows. In the progression of tasks, a square path was gradually built by adding complexity: from the request to interpret a given code (forward-forward-turning) to then move the bee from one flower to another (passing through a third flower in a way that the bee can travel an "L" shaped path, then a "U" shaped path). In so doing, the teacher focused on a back-and-forth movement from imagining the code (or robot motion) to impersonating that code/movement or coding the robot, which allowed for reasoning on the tool in terms of bodily interactions (Ferrara, 2014; Nemirovsky et al., 2013).

PRELIMINARY INSIGHTS FROM THE ACTIVITIES

We present an episode to discuss initial insights coming from the teaching experiment, which informed the design of the activity. During the first activity, after the children have compared the different lengths of the paths between the flowers using their footsteps, the teacher gives the children the cut-out figures of a foot and flowers to glue on a sheet of paper to describe the previous bodily experience. Pairs of children of different ages are now working on the task. The researcher (R) approaches a pair of girls (Camilla, C, 3, and Mia, M, 5) who have already positioned two sets of flowers on a sheet (see Figure 4) and asks them:

R: What did you do?

M: We made longer paths.

R: Which is the longer path?

M: This (*points, Figure 4, left*)

R: Because I see two paths…

C: And this is the shorter one! (*points to the shorter path)*

R: Why that one (*points to the sheet*) is the longer one?

C: This one!

M, R: Because it has more feet

C: Yes, this is the longer one, and this is a little shorter (*points to the two paths*).

R: And how many steps are there?

M: One, two, three, four. One, two (*counts the feet on the two paths, Figure 4, middle*)

R: So, how can I do to see if one path is longer or shorter?

M: It shows, and if you turn it, you see it better (*shows the sheet to the camera, Figure 4, right*)

Figure 4. Mia and Camilla comparing lengths of the two paths on the paper sheet

The two children work together on a task that is preparatory to coding activities that require using a sequence of "steps" to describe and create a movement in space. The "foot" prepares the ground for the one-to-one relationship with the Blue Bot movement embedded by the code. We discuss this episode in terms of the aspects that we see as enriching the experiences of the children: the analysis is meant to highlight how the girls *make* and *make sense* of their drawing. In the brief interaction with the researcher, the two girls use the created representation to compare the lengths of the paths. They produce a first argumentation about the contextual experience of the number of feet; that is the paths are of different lengths. At the end of the brief excerpt, Mia changes the drawing position to allow the researcher "to see it better". This funny moment speaks directly to the way in which the girl comes to inhabit the representation: for her, the privileged position to look at the drawing is the one in which they explored the movement from one flower to another. After, Mia exchanges the position of a blue and red flower to match the colours. Then, the girls add a much shorter path to their drawing (one foot only). They notice details that count in the description of a movement, even if only to adhere to the previous bodily activity, distinguishing between the starting point and the ending point through colour; they also explore new variations, using the foot as a measuring unit. The two children collaborate, despite the difference in age, and converge on a common narrative that establishes a comparison between the two paths, using numbers and a first measuring unit (the foot). Later in the teaching experiment, when the children programmed the Blue Bot to move it from flower to flower (a straight path across the classroom floor), we observed peculiar behaviour. Some children scanned the space in between and pressed buttons on the robot as they moved their eyes to the farthest flower as if they were imagining a movement happening in front of them. Further discussion is needed on how such activities can foster the use of the tool and promote spatial thinking and will constitute future research.

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