Educational Robotics at Primary School with Nintendo Labo

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Abstract In the last five years, the Italian Ministry of Education has focused on digital skills, recognizing them as fundamental and indispensable for the growth of the future citizens of the information age. Numerous requests have come from the European Commission, the Italian Ministry of Education and the employment world regarding the introduction of new technologies in schools, whether or not this is part of curricular activities. National guidelines for kindergarten and primary school curricula promote the introduction of new tools and new multimedia languages as fundamental for all disciplines. The idea of the National Operational Programme (PON) and the National Plan for Digital Education (PNSD) is to boost digital knowledge and participation in STEM subjects. The project presented in this article was launched in this context and was a collaboration with the Nintendo company to evaluate the “Nintendo Labo” product at educational level. This trial was conducted in a third-grade class at the “Allegretto di Nuzio” primary school in Fabriano (AN). The kit, an evolution of the Nintendo Switch console, was initially created for recreational purposes. The advantages and limitations of the product came to light during the few months of the experiment. The “Nintendo Labo: assembly—play—discover” educational project allowed students to merge theoretical and practical aspects of their knowledge, and understand complex systems through design and simulation.

Keywords Digital competences · Coding · Educational robotics · STEM · Primary school · Nintendo labo

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1 Introduction

Many researchers have investigated the use of coding and robots to support education, showing that robots can help students develop problem-solving skills and learn computer programming, mathematics, and science. For this reason, the authors conducted an experiment in primary schools using innovative kits that can be customized with cardboard. While considering how to engage girls and boys in an activity with the potential to motivate them to consider a future career in STEM-related fields, the authors drew on personal experience (see [1–6]) and on the great results found in the literature achieved using coding and educational robotics (ER) for the same aim. First, Benitti et al. [7] reviewed ER experiences around the world, showing that there is great potential in ER methodologies and activities in K12 classrooms, but the full power of these research outcomes still needs to be thoroughly exploited. In fact, [8] Mubin et al. highlight the great effort that research still needs to produce appropriate curricula that include robotics. Veselovská et al. [9], on the other hand, present a qualitatively assessed ER activity in the context of an ER curriculum at lower secondary school level. Sanders et al. [10] consider robotics to be the integrated approach to STEM education: rather than these four subjects addressing it separately as merely a set of notions, they could come together to re-elaborate these notions as part of active learning.

2 Material and Methods

The pedagogical theory used for the design and execution of the activities in this project is constructionism. Its premise is that knowledge building is the natural consequence of creating and experimenting. Students are encouraged to use the materials at their disposal, directly observe their actions and analyze the effects. For these reasons, Nintendo created a kit with cardboard cut-outs and other materials, such as laces, elastic bands and infrared-reflective stickers. All the materials have to be assembled using the Nintendo Switch console display and Joy-Con controllers to create a “Toy-Con” that can interact with the included software. Nintendo designed Labo as a customizable technological game. In Italy, marketing for the product began in April 2018. The application to begin the project—to test whether the product could be used in Italian primary schools—was submitted in July for the 2018/2019 academic year. Although the product was originally designed for recreational purposes, its functionalities have since been appreciated and deemed useful for teaching the principles of engineering, physics, and basic programming. In each of the aforementioned “Toy-Cons”, the paper parts and the controllers called “Joy-Cons” enabled each artifact to become programmable and interactive, thanks to augmented reality. During the project, students invented new ways of using the cardboard, programming and placing the controllers in housings other than those designed by the manufacturer. At the end of each design phase, the console was connected to a projector and all

the groups could invite other classmates to the “game”. The classroom experienced extraordinary levels of cooperation, which in turn reduced distraction and bullying, and increased participation. Nintendo’s images were projected onto an erasable wall. This had the advantage of involving students in a phase of reengineering, drawing, commenting, and reporting. The company’s assembly instructions for the Toy-Con were loaded into the software. The projected images were surprisingly engaging for students. The various steps were described in three-dimensional animations and there were special functions to stop, rewind or fast forward the film. In Nintendo Labo, all actions on the software could be linked to the hardware, so it was easy to let the students proceed by trial and error. This characteristic helps students who have motion or reaction difficulties. The “Garage” feature enabled students to program according to the principle of “if... then...”, which is typical of cooperative-learning, using the: “Causal Node” and “Effect Node” functions. Students could create the Causal Node by simply placing elastic bands on the programmed junctions on the console (i.e., like guitar strings). Once the “if you touch” command was assigned and activated by plucking the elastic, an Effect Node was activated (i.e., the console emitted a sound when the “if you touch” command was assigned to the “play note” command in the corresponding Effect Node). The junctions between the nodes, which appear as icons, can be displayed by tracing a line on the console touch screen with a finger. This helps children become accustomed to recognizing nodes graphically as relationships in a mind map that becomes more complex with the addition of the “and” connection.

2.1 Learning Objectives and Competences, Expected Results

The learning objectives and competences considered in this first part were:

- Promoting and developing new knowledge and competences in computational thinking, coding and the use of digital technologies.
- Improving soft skills, especially critical thinking, analytical, problem-solving, and planning skills, and teamwork.
- Reinforcing logical reasoning.
- Increasing interest in STEM, robotics, and coding.
- Improving the learning process and school performance to motivate the students involved in the project.
- Improving teamwork.
- Learning the very basics of coding.
- Experimenting with the “Toy-garage” software implementation strategy.
- Creating a simple robotic artifact that can interact with the environment.
- Acquiring the ability to build cardboard robots for specific and relatively complex purposes.
- Presenting artifacts that can represent a “causal node” or an “effect node”.

- Creating a PowerPoint technical manual for the final operator explaining how to design and implement the objects created.

Throughout the project, the use of poor quality, structured and unstructured material helped increase awareness of different materials, and the ability to predict their characteristics and effects. The main objective was to increase logic in the consequentiality of the actions undertaken, so that students would become accustomed to verifying scientifically on the basis of how materials behave. Another important goal was to get the students used to visual programming based on conceptual maps, to promote metacognition, which makes students aware of their choices. No less important are the cross-cutting objectives: collaborating with classmates, making positive contributions to the group, learning to accept others through cooperative-learning and problem-solving.

2.2 Contents of the Activities

The first and main objective of this project is introducing robotics and coding to primary school curricula, and proposing them as extracurricular activities. Robotics give students a different opportunity to develop their logical skills and creativity, which are essential features of reasoning and critical thinking.

2.2.1 The Radio-Controlled (RC) Car Activity

The first activity in the experiment was constructing a radio-controlled (RC) car. Each student had his own cardboard kit, which they folded to assemble, learning the importance of being accurate and precise at each step. They had to manipulate the die-cut cardboard sheets while avoiding folding it in the wrong place, which could compromise the result. Only when the Joy-Con was inserted did students have proof that their artifact was correctly assembled. Two Joy-Cons (controllers) are needed for this Toy-Con, and can also be customized with cardboard and programmed remotely from the portable console. Acting on the frequency (“Hertz”) of the two devices, placed on the sides of the car, students see the latter move in different directions. Vibrations will affect the cardboard parts that are in contact with the support surface. Once the structure was completed and the functionality of the movements was verified, students personalized their cars by adding colored cards, acetate sheets and yarn. The innovative nature of cardboard-based robotics undoubtedly attracted students to the customization phase, motivating them through trial and error, without the frustration of the feeling of failure. Next, in the speed competition, students discover how different materials and thicknesses behave, depending on the vibrations they are subjected to. Those who used thicker or heavier materials definitely found they lost speed or accuracy in their movements. However, the desire to find errors and ask questions about the unforeseen events stimulated them to try different things

and explain the solutions they found to the class. It was easy to link the objects created during the project to topics studied in the third grade. After the RC car, the students were asked to build a project linked to their subjects, and create a description in Italian with an explanatory drawing or diagram showing how to use it. Many children redesigned the RC toy car as a dinosaur and linked it to the prehistorical period they had recently studied. The background flora was created from the same materials using the snap-fit mechanism, and a storytelling activity was set up about prehistoric times. Groups of students took turns in a storytelling and coding activity with the console, and applied it to the dinosaur paperboard. When the dinosaur got to a certain place, the child controlling its movements had to answer questions to be able to continue. From time to time, the path and the setting changed, depending on how the workgroups were organized. Stimuli were given to encourage the students to cooperate and help each other. Along the way, students added reflective labels to trees or bushes built to create “autopiloted” functions. They simulated food on the trees (cubes that could be pushed to show new variables and activate mechanisms, or to trace pathways in places where there was no light). The background and the path were enhanced with questions and mathematics exercises related to the school program. As the activities progressed, students created new robots autonomously, to which they added Joy-Cons. Some of them transformed a truck into a mammoth or a unicorn into an excavator. At the end of the RC car activities, the infrared camera was tested. A new background was designed, with a path added to a box. Students observed from different points of view, that is, no longer from top-down but also from the front. This led them to experience positions in space and points of view based on what they had studied in geography. The RC car activity was also easy to link to the topic of planting strategies they had learned in history. Students developed an RC seeder, enabling them to add a seed compartment with bottlenecks to drop the seed according to the vibrations generated remotely. The seeder was tested in a new scenario with hills, mountains and a maritime setting (subjects studied in third-grade geography).

2.2.2 The Fishing Rod Activity

Constructing the fishing rod was useful practice for some of the theories students learn in science and mathematics. Students built the robotic rod and “fished” interactively. As they held the rod they could observe the images of the marine environment and their hook projected against the wall. The fishing activity exploits the differential command of the controllers. Two controllers were applied to the handle and the reel of the rod to capture movements during the virtual fishing exercise. The fishing simulation allowed students to explore the behavior of different species of fish at different depths. Their motor coordination was exercised as they moved the rod and the resistance sensors responded. Furthermore, for each fish they caught, the scientific name was highlighted, its weight was shown in multiples and sub-multiples of kilograms, as was the total weight of the catch. The activity involved practicing sums, equivalences and transforming units of weight. Students learned about gross,

tare, and net weights. All this took place in a playful atmosphere, with the class divided into teams. Those who could not answer quickly were helped by the other members of the group. Using the tools in the kit, the students drew their fish on cardboard and twinned them into the virtual sea at a precise depth where they are supposed to live. The exercise was also useful for practicing weight estimation.

2.2.3 The Motorcycle Handlebar Activity

Designing and building a motorcycle handlebar with controllers inside the knobs gave students a full immersion into a virtual world. Taking advantage of the immersive potential of Nintendo, students created a teaching aid for students with dysgraphia or taking their first steps in handwriting. A group of students prepared a physical track for the motorbike in the shape of a letter. Meanwhile, other groups created the digital counterpart of the track. The virtual letters (tracks) had a motorbike on them that was controlled via the physical handlebar. As they drove the virtual motorbike along the tracks, the students drew virtual letters, a more engaging experience for them than doing traditional writing exercises using their fingers or a pencil.

2.2.4 The Piano Activity

Designing and assembling a cardboard piano brought the Toy-Con concept to music lessons, where the new technological instrument could be used alongside traditional instruments. The piano plays because a controller with an infrared sensor detects the movement of the cardboard keys, which have reflective labels, and the console processes the right note. Each step in the procedure was projected onto a screen for the entire class to view. The students programmed tones, sounds, distortions, and recorded audio. The last activity saw the class create a virtual solfeggio by holding a controller programmed to modulate the tone. Each movement of the hand corresponded to a change in sound.

3 Developments and Preliminary Results

The experiment took place in the 2018/2019 academic year and validated quantitatively the introduction of the Nintendo Labo system to the primary school curriculum as an educational tool. After getting acquainted with the commercial tool and its proposed activities, it was decided to set aside the suggested transmission approach in favor of an interactive approach. Teachers and students customized their artifacts with a variety of objects, such as blocks of wood, sheets of acetate, paper and cardboard of different thicknesses, straws, yarn, colors, aluminum foil and objects easy to find at school. In this way, learners could put their creative skills to work personalizing these artifacts, through what M. Resnick calls the “spiral of creative

learning”. Students held various objects in their hands, identified their characteristics and imagined what to create. As they played with the kit and the available material, they shared ideas with other group members, and thought over what they could do. Although the materials differed, the essence of the learning process was the same. Children perfect their ability to think creatively and develop ideas by writing down projects and illustrating them to others; in turn they learn to consider alternatives and to take cues from others. Programming through the “Nodes” enables them to acquire new knowledge and computer skills while playing. When a child tells others about the new technological features they have discovered, or a new way of connecting the cardboard pieces, she gives others the opportunity to share in the creative moment, not only incrementally but also cooperatively. The teacher’s function is not only to transmit knowledge and facilitate a learning dynamic respectful of the rules, but also to co-experiment. Students then took part in a STEAM-related experiment in ER, with structured and non-structured materials, which combined tinkering and making. Two-monthly reports were sent to the company on the work done by the students. The experimental work took place in the multi-purpose laboratory of the “Allegretto di Nuzio” primary school, created in collaboration with the Loris Malaguzzi International Center, and Reggio Children. The laboratory was designed as a creative atelier by a team of pedagogues, architects and experts in education. The colors of the walls, the mobile and flexible furniture, and the technological instruments, such as cutting plotters, 3D printers and magnetic walls, were beneficial for the aims of the work. One of the purposes of the technology was to foster the conscious and intelligent use of the resources by the children. The activities show that this methodology encourages them to master the fundamental concepts of technology and how they relate to each other: needs, problems, resources, processes, products, impacts, control. Italian Law no. 107/2015 and Legislative Decree no. 62/2017 call for activities related to computational thinking. Thanks to the programming of the console, which is interfaced with the sensors in the paperboard, the students’ mental processes were challenged to solve problems. From time to time, solutions arose from specific methods and tools and through strategy planning. This was particularly the case for those situations that called for the construction of a procedure, a series of operations to solve a problem, or the establishment of a network of connections.

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