Sorting Materials using Programmable Lego© Robot: an Educational Activity to Promote Sustainability among Youngsters

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Abstract

Educational robotics is a powerful, flexible, teaching and learning tool. At the same time, it can be used for presenting scientific concepts and it can help to develop scientific thinking, inquiry practice, information literacy competences, and attitudes and accountability as well as the environmental awareness. In the framework of the European Green Deal and the national project "Change the Game: Playing to Prepare for the Challenges of a Sustainable Society", we engaged groups of students in two learning paths focused on building and programing robots able to face the material recognition and recycling. The pathways were developed in two weeks' extracurricular stage in institutes of the Italian National Council of Research (CNR) and were based on colour sensing, deal with the sorting of different materials: (i) plastic caps and (ii) mosaic tiles. Lego© Spike Essential kit were used as hardware and software tools. The learning paths began with an introduction to the scientific topic. During the two weeks, meetings were organized with other researchers and experts and the pathway continue with the mechanical construction and programming of the robot. Finally, the students presented their creations to the public. In the case of the robot sorting caps, colour selection allows the efficient recycling of plastic (HDPE) for the production of new objects with well-defined colour characteristics. As regards mosaic tiles, they are often obtained from production residues that are marketed in the bags of multicolour fragments. The need therefore arose to automatically separate the glass tiles based on their colour to relieve the artist from this tedious task. Different convincing solutions both in the mechanical assembly and in the software development have been obtained thanks to the creative work of the groups. At the end of their extracurricular stages the students have been asked to run a workshop in which they presented their robot projects to small groups of other students and helped them build and program the robots, thus reinforcing their skills and transferring them to their peers, in a virtuous learning circle.

Keywords: *STEM, LEGO, Recycling, Sorting, School, Educational Robotics*

1. Introduction

Educational robotics offers countless opportunities for group work and self-evaluation [1,2]. Robotics can be used as a tool that offers opportunities for students to engage and develop computational thinking skills [3] and is usually seen as an interdisciplinary activity drawing mostly in Science, Mathematics, Informatics and Technology (STEM) and offering major new benefits to education in general at all levels [4]. Educational robotics can help not only to develop scientific thinking, inquiry practice, information literacy competences but also it can be used for presenting scientific concepts and raising i.e. environmental awareness in the classroom. The latter aspect is particularly important for contributing to the transition towards a more sustainable society promoted by Europe. In fact, the Agenda 2030 [5] and the European Green Deal [6] are challenges and opportunities also for triggering the interest and the social awareness to the youngers in a sustainable society and to show the importance of research in facing innovation.

Challenges in promoting together educational robotics at school and learning for the green transition and sustainable development, include insufficient appropriate learning materials, a lack of expansive

learning activities and tasks and limited opportunities to engage students in the process of design thinking and developing metacognitive abilities.
In the past years, several STEM learning paths for students aged 10–18 years have been developed in the framework of an Italian national network ("Il linguaggio della Ricerca") of researchers from the National Research Council of Italy (CNR), collaborating with schools, scientists, and experts in science communication and dissemination [7], as well as in the European network of Raw Matters Ambassadors at Schools (RM@Schools), developed thanks to a European project funded by the European Institute for Innovation and Technology (EIT) [8-9]. More recently, new learning pathways aimed in raising the interest towards sustainability and implementing serious games has been designed and tested thanks to the Italian national project entitled "Change the Game: Playing to Prepare for the Challenges of a Sustainable Society" [10].
With the aim of integrating new tools in the CNR formative offer for schools, we set up a play-based learning path focused on building and programming robots able to face the material recognition and recycling. We chose to use this methodological approach since it is known that learning through play is an important strategy to promote student engagement, inclusion, and holistic skills development.
Here, we present two new robotic pathways set up in 2022-2023 and implemented in two weeks' extracurricular stages by high school students in CNR institutes. These pathways use colour sensing to sort different materials, specifically plastic caps and mosaic tiles.
Sorting is the first step of the recycling process, an important component in developing a sustainable society. In fact, waste is a massive problem and for businesses, sorting the trade waste they produce is a critical component of an effective reuse and recycling system. For businesses, the benefits of proper waste segregation include lower waste costs and lower landfill impact, since mixing waste streams can be costly and can cause environmental issues, increased recycling rate and *potential revenue* streams because segregation enables to identify valuable materials and sell them to achieve the highest available rebate value. Thus, it is important to raise the interest by high schools' students not only towards the recycling topic but on sorting waste which makes easier to understand how to reduce general waste output, identify items that can be reused and set aside items that should be recycled.

2. Pathway structure

The robotic learning pathway for high school students is built using a modular structure with four phases as shown in Figure 1. The first step is the definition of the project with the help of frontal lesson and open discussion followed by introduction of the task to be solved. In the second phase, the students visit research laboratory and meet experts in the field. The core of the activity is the software and mechanical building of the robot including its test and improving. In the last phase, the students are involved in the final testing, the writing of the report including the building instructions and the results presentation in public dissemination event.

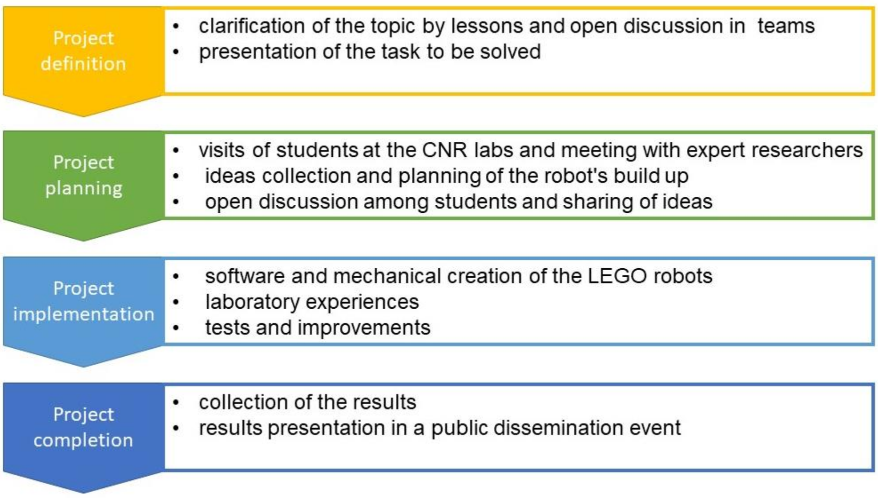

Fig. 1. Modular structure of the robotic learning path

The Lego Spike Essential Kit provides a complete hardware set that includes sensors and actuators together as well as a software development environment. It is appropriate for students aged 8 to 16, and no prior programming experience is necessary. This kind of educational kit is typically available in primary and secondary schools. The two robotic learning paths tested in 2023 were based on colour sensing, deal with the sorting of different materials: (1) plastic caps and (2) mosaic tiles.

2.1 Plastic cap selector

High density Poly-Ethylene (HDPE) is a thermoplastic polymer commonly used as cap of plastic bottle. It can be easily reused simply by melting. Mixed colour caps diminish the value of the recycled material due to the poor control of the colour in the final product. For an efficient recycling of plastic cup, colour selection allows a more valuable recycling of the used material, allowing production of new objects with well-defined colour characteristics [11].
In this pathway, an example of a "Cap Selector" is made with an inclined chute that feeds the caps under the color sensor one at a time (Figure 2a) [12]. A mechanical arm directs the cap to the right or left depending on the color recognized by the color sensor. As the cap comes out, the next cap moves (slides) under the sensor and the cycle repeats 8 times. The programmable brick has only two ports connected to the color-sensor and motor. The software is shown in Figure 2b using word block. During each cycle, the robot reads the color-sensor's value. If the detected color matches the predetermined one (red in the program shown), the motor moves clockwise; otherwise, it moves counterclockwise, eventually returning to the central reference position.

a **b**

Fig. 2. a) Cap selector in action and b) the code of cap selector.

2.2 Mosaic tile selector

Mosaic tile art has recently experienced a significant revival in artistic and decorative use. The mosaic tile selector promotes the re-use of glass tiles production waste of, which are marketed in bags of multi-colored fragments, as an alternative to purchasing new tiles.
The robot was designed by taking inspiration from the Plastic cap selector. A first solution (Figure 3a) is a system employing wheels and elastic bands to transmit the rotary motion to a bush and a conveyor belt (comprising two parallel elastic bands). The bush selectively picks one tile at a time, even with variations in the tile shapes, and it moves the selected tile to the conveyor belt for color detection. The primary challenge was coordinating the bush with the conveyor belt, leading to occasional jams and the limitation of sorting tiles into two different positions, allowing for the selection of only one color at a time.
A second solution (Figure 3b) uses an inclined ramp set at a 22° angle to slide the tiles under the color sensor. Mechanical arm then directs the tiles in one of the four different directions based on information of the color sensor.

a b

Fig. 3. Mosaic tile selector: a) the first solution [13] and b) the second solution and its code [14].

This configuration has the advantage of separating tiles of four different colors simultaneously and monitoring the quantity of tiles in each category using dedicated counters. A possible improvement would be the integration of a more powerful motor capable of handling larger and heavier tiles.

For optimal performance, the system requires a large number of tiles that push against each other, promoting sliding without external intervention.

3. Implementation

In total, we have conducted two training stages (80 hours) dedicated to the robotic pathways organised and supervised by the researchers, authors of this work. A group of two students was hosted in Florence (CNR-ICCOM, CNR-ISC, CNR-IBE) both working together on the plastic cap recycling. Four students divided in two groups in Faenza (CNR-ISSMC, CNR-ISOF) worked on mosaic tile selector. The students in Florence visited chemical laboratories for the synthesis of new catalyst used in the production of renewable plastics and they attended at the analysis of plastic materials using X-ray diffractometer and electron microscopy. In Faenza, the students visited the cultural heritage laboratory, where they had the opportunity to use the 'martellina', a special hammer to chop the mosaic tile, and the electrical characterisation laboratory where they experimented the use of piezoelectric ceramics both as actuators and as sensors. Although the different groups of students were physically distant, they benefitted from a moment of online group discussion where they had the opportunity to share successes and difficulties in developing their projects, as well as their experiences at the research institutes. Each group prepared the building instruction of their robot including the code used (see Figure 4) [12-14] and made a presentation of their work and results in front of the institute's researchers and teachers.

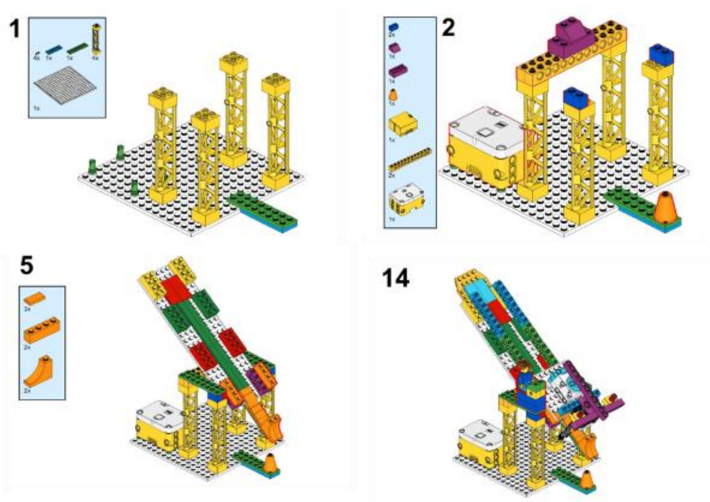

Fig. 4. An example of the building instructions.

Once the internship period was over, the students were involved in a dissemination event organized by “Il linguaggio della ricerca” at the CNR in Bologna. During this event they tutored two robotic LEGO workshop for high schools’ students so they were engaged in peer-to-peer training activity (Figure 5).

Fig. 5. LEGO robotic workshops tutored by High schools’ students at CNR Area in Bologna (IT)

4. Conclusions

A learning pathway focused on building and programming robots capable of sorting materials by colour was designed and implemented in two research institutes of CNR. The pathway was successfully adapted to the specific research areas of each institute, so linked to the running research. Educational robotics was used to engage high school students, develop their computational thinking skills, introduce them to scientific concepts, and raise their awareness of the environment. The building instructions produced by the students will be used to design other learning pathway dedicated to sustainable development for students of elementary and junior schools.

The study offers innovative educational materials and activities aimed at promoting educational robotics and learning for sustainable development and the green transition, which contribute to Europe's transition towards a more sustainable society.

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