Students' Engagement through Computational Thinking and Robotics

Michela Tramonti[1, 2 [0000-0003-0098-863X]], Alden Dochshanov[2[0000-0001-8265-8639]]

[1] Institute of Mathematics and Informatics, Bulgarian Academy of Science, Sofia, Bulgaria
[2] EU-Track - European Training and Research Association for Cooperation Key to Business, Terracina, Italy
m.tramonti@eu-track.eu, a.dochshanov@eu-track.eu

Abstract. Nowadays, school systems are underlining the relevance of "computational thinking" and educational robotics not only in STEM (science, technology, engineering and mathematics) education, but also in other humanistic disciplines as reinforcement of student creativity and problem-solving capacity.
This paper presents an example of educational robotics tool used to engage students in their learning process through the manipulation and construction of artifacts.

Keywords: Robotics, Technology-enhanced learning, Inquiry-based learning, Learning by doing.

1 Introduction

During the last years, school systems have recognized the relevance of algorithm thinking, or computational thinking, and computer coding to be taught starting from primary school. The main idea is that knowledge and informatics skills can't be restricted to the use of devices or software only, but they should be integrated into the teaching and learning processes to let students approach the informatics and coding principles {Bosciani M., 2016 #135}. The last, in its turn, permits students to develop logical and analytical thinking aiming to solve problems in different contexts of such an approach as educational robotics.

The methodology favours the development of students' potentialities, because provides the immediate and concrete applications. This contributes to the competences and knowledge construction in mathematics, science and technology from one side and in entrepreneurship and language from the other {MIUR, 2018 #136}.

The goal of the paper is to describe an example of developed educational robotics tool aiming at student learning reinforcement within the context of scientific and humanistic education.

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2 Computational Thinking

On the base of the definition stated by Jeanette Wing, Computational thinking "involves solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science. Computational thinking includes a range of mental tools that reflect the breadth of the field of computer science"(J. M Wing, 2006). However, a further development of her definition, introduced in 2011, states that "computational thinking" as the thought processes involved in formulating problems and their solutions are represented in a form that can be effectively carried out by an information-processing agent"(J. M. Wing, 2011).

Therefore, two key elements for "computational thinking" can be identified. Firstly, it should be considered as a reasoning process and, consequently, independent from the use of technology. Secondly, it can be referred to a different way of "problem solving" requiring specific abilities related to the problem definition; data and analysis logical organization; models and simulation development for data visualization; an effective combination of resources to reach possible solutions found and to be applied to different contexts and situations (Bocconi, Chioccariello, Dettori, Ferrari, & Engelhardt, 2016).

This promotes development in young people of the thinking ability in a different way during problem-solving reasoning through the analysis of the same situations from different points of view (Lee et al., 2011) by promoting student creation and innovation capability.

In this context, the "computational thinking" promotes the abstractions of real-world problem by designing and reasoning on computation artefacts such as programs or coding (Bocconi et al., 2016) which becomes the understanding way of the mental or written execution. Thus, coding makes computational thinking concepts more concrete and turns them into the tool for an effective learning.

For this reason, the "computational thinking" is not strictly related to the coding but to a reasoning process.

To give an example, a way how to use the computational thinking may be seen at the learning approach model proposed in the PhD research (Tramonti M. , 2017a) aiming at reinforcing the comprehension of mathematics of secondary school students through the 3-phase educational approach, namely concrete, pictorial and abstract based on the Singapore method applied to the mathematics study. In particular, at the first stage, named "concrete", students are required to develop the computational thinking, because they are supposed to manipulate different objects, strictly connected with mathematical concepts through the specific software, e.g. Geogebra, Logo, Scratch (Tramonti M. , 2017b).

3 Educational Robotics

An immediate application of "computational thinking" can be found in educational robotics, which can be regarded as a teaching approach to several subjects through different cognitive artefacts. This means that "educational robotics" is not a synonym of teaching robotics as a pure discipline, and therefore neither just a teaching coding applied to robots nor the study of how an android works.

In general, it is a teaching methodology, engaging students into problem solving, learning by doing, that favours the development of "computational thinking" by including a constructive approach to the error.

In fact, being mainly driven by the basic learning and teaching strategies implemented in this sector, i.e. discovery and inquiry based learning, team working, problem solving that significantly favour the investigation, a positive role of the error is recognized. In this context learning becomes more effective, because student knowledge construction is supported by the realization of a concrete, meaningful project, when every mistake made or challenge faced continuously stimulates students' curiosity.

Through the use of this methodology it is possible to introduce students to both specific and transversal skills and relate them to school disciplines both directly or indirectly. For this reason, taken in this perspective, educational robotics is not a single discipline, but rather a tool, deepening the comprehension and disciplines perception in general.

Based on the constructivist approach, as defined by Saymour Papert, where the learning process is student-centred whose active role determines knowledge construction (Papert, 1994), the methodology supports students in creation and designing of a didactic pathway focused on the concrete objects manipulations (Dochshanov A. , 2017) (Dochshanov A.; Tramonti M., 2018).

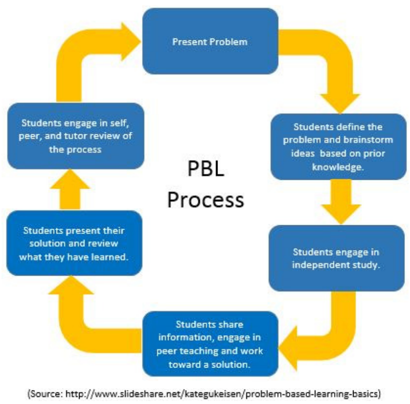

Fig. 1. Problem-Based learning process (educational robotics implementation).

Due to the specificities of the methodology, it is not exclusively applied in technical and scientific fields, i.e. in STEM group disciplines (sciences, technology, engineering and mathematics), but it also promotes an interdisciplinary works by including other subjects such as Art, Music and Literature as well (Miotti B., Guasti L., 2018).

3.1 Robotics tools and settings

In educational robotics, different technological tools and settings can be used. The last depends on the complexity and target skills that teachers or instructors wish to stimulate. As a result, the robots or robotics elements used vary in correspondence with the school level and students' age.

On the market, numerous educational kits exist (Ruzzenente, Koo, Nielsen, Grespan, & Fiorini, 2012) aiming at the unplugged mode experiment path working and thus promoting individual imagination and creativity.

However, starting from the primary school, young students can deal with more complex tasks addressed to the manipulation and construction of cognitive artefacts by using coding software.

An example we introduce here is represented by Robo-1 with functionalities similar to market product, *Bee-bot* (Fig.2).

Fig. 2. Left: Robo-1 model: a) top view includes the control buttons and performance indicator; b) back view with the switch on-off button; c) general view of the robot; Right: Bee-Bot robot.

Robo-1's core hardware is Arduino board and L293C Quadruple Half-H drive IC. As can be seen from the Fig. 2, the robot's case is the painted Smartphone packing cardbox to promote the idea of the recycled materials use.

In the view of educational effectiveness, the use of this analog of commercially available Bee-Bot, has a number of undeniable advantages.

First of all, while Bee-Bot attracts attention in terms of elementary coding, whereas the accompanied development and consequent use of our robot model permits to obtain a deeper insight not just onto the "high-level" programming, but to perceive the direct interrelation between the software and hardware at different levels, using the Arduino-coding.

For example, while regulating the accuracy of a single 90^{o} turn, students have at their disposal direct software instrument (Arduino IDE), and L293C DC motor driver to have an immediate feedback to see and use it in a further adjustment (see Fig. 3).

Thus, playing around the value of constant "action", which in the program represents the duration of a turn in milliseconds, at physical level students impose the accuracy of a turn, provided with an appropriate polarity applied to the DC motors through the H-bridge IC.

Secondly, as shown earlier, students are equipped with all necessary to understand deeper the interrelation between mechanical, electronic and software components of the project, due to the final task contextualization, i.e. to perform a pre-preprogrammed move sequence.

Thirdly, Robo-1 when compared to Bee-Bot, is not a closely finalized project and can be easily extended further by adding the additional sensors (e.g. ultrasound detectors), thus enabling more advanced functionality and more sophisticated tasks to perform.

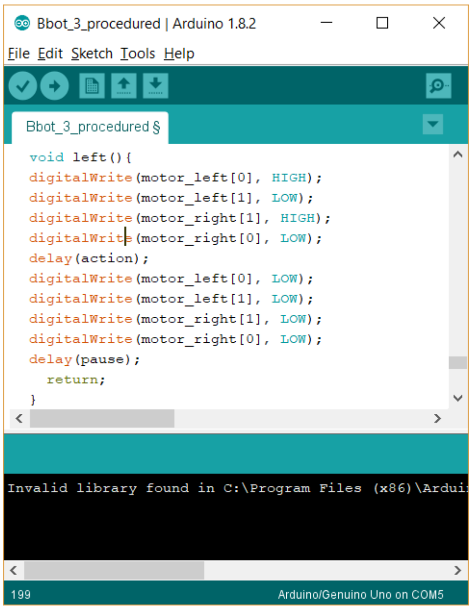

Fig. 3. Arduino IDE window displaying the auxiliary procedure "left", where the constant "action" responsible for the turn duration.

4 Conclusions

The introduction of the educational robotics tools can make teaching and learning processes more effective and motivating through the manipulation and construction of artifacts.

The paper has shown an example of the Arduino platform-based robot with extendible functionalities with respect to the commercially available Bee-Bot. At the moment the methodological scenarios for its introduction in the secondary school curricula are at the definition phase and they will be tested with students by the end of the year. The final goal is to verify the applicability and versatility of the tool developed for different teaching and learning settings and to reveal the potentialities of the students' creativity promotion both in finding possible problem solutions and their applications.

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