Teaching Physics Concepts Using Educational Robotics

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Abstract. This paper reports a study included in the national project PROMISE funded by the Italian Ministry of Education, University and Research. It examines the application of an educational robotics laboratory with secondary school students for learning concept about physics. In the paper we describe the didactic strategies that have been implemented during the activities and we give some qualitative outcomes related to effectiveness of the laboratory. Indeed we observed interesting results in students both in term of learning and of interest and participation. The importance of teacher involvement in this type of intervention will also be discussed.

Keywords: Educational robotics · Physics teaching/learning · Cooperative learning

1 Robots as Educational Tool

In recent years, Educational Robotics (ER) has been used for developing many competencies: several studies have shown that educational robotics is positively correlated with cooperative learning and the sense of individual and collective self-efficacy [1]. Other studies showed that the students who used the robots achieve better results in learning concepts such as space and distance [2], geometry [3], spatio-temporal relations [4] and Genetics [5]. Caci, D'Amico and Chiazzese [6] demonstrated also that robotics labs may improve specific cognitive skills such as visual-spatial working memory. Moreover, all these studies evidenced that students are very collaborative and motivated in carrying out the robotic activities.

2 The PROMISE Project

Starting from these results, we performed a study aimed at use ER as a teaching/learning support tool for the didactic of Physics.

The study was carried out inside the national project "PROMISE" (Progetto RObotica Educativa: Musei, Imprese e ScuolE). PROMISE has been funded by MIUR (Italian Ministry of Education, University and Research) and realized thanks to the

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collaboration of many public and private entities such as: Scuola Superiore Sant'Anna (lead institution), University of Milan-Bicocca, CNR (Institute of Educational Technologies of Palermo), University of Siena, University of Palermo, MetaIntelligenze Onlus, PalermoScienza, National Network of Schools for Robocup Junior Italy. The project aimed to create a national network of educational robotics involving schools, museums, and companies and, in particular, to train 36 teachers and 24 experts in the use of educational robotics in learning contexts. Both teachers and experts attended a training course and also performed a 36-h internship for applying the skills acquired at school or in museums.

3 Teaching Physics Using Educational Robotics

Our study concerned the use of robotics for teaching/learning concepts of physics related to energy and motion. A class of 21 (mean age 16 years), attending the 3rd year of a scientific secondary school, participated to the study. The activities were conducted by their math and science teacher, who participated to the PROMISE Project. An experimenter from our team followed all the activities as observer.

Five LEGO Mindstorm EV3 kits and 5 PCs were used in the school's computer lab. The 21 students were divided in 5 groups, so that each group had the opportunity to use one robotic construction kit. The ER activities were carried out in 6 weekly meetings lasting two-hour each.

During the meetings the students studied some topics about physics using ER. They realized several experiments that included the application of formulas on motion and energy for programming the movements of robots for solving some problems, as described below. At the end of each meeting, the students showed the programs to the other classmates, exposed the main problems they had encountered and illustrated the solutions they had found to solve them.

3.1 First Meeting

During the first meeting the students took a look at the main programming blocks related to the movement and use of the sensors. After a brief introduction, they were left free to perform two simple robot movement programs by using sensors to avoid obstacles or to stop when a specific condition occurred.

3.2 Second Meeting

The second meeting focused mainly on the use of "flow" programming blocks (loop, switch, wait …) and "data operation" (variable definition, mathematical operations and arrays) necessary to apply the motion formulas in subsequent meetings. The students followed a tutorial and created a program that used these functions.

3.3 Third Meeting

During the third meeting, after the study of formulas to calculate the motion and the relative inverse formulas, each group had to solve a problem about physics by using robots. The first step was to calculate the robot speed, that is not defined in EV3 construction kits. In order to achieve the focus, they used a meter for calculating the length of a path and a stopwatch for measuring the time that the robot needed to follow it. Once students owned information about space and time, they could derive the robot speed. This information might then be used to predict the travel time of the robot along a straight path or, applying the inverse formulas of the uniform rectilinear motion, for measuring the length of different surfaces.

3.4 Fourth Meeting

During the fourth meeting the students were asked to implement a program that calculated the speed and acceleration of the robot through the radius of the wheels and the number of rotations of the engine. By using the "data operation" programming blocks, the robot can be programmed to perform calculations, by using variables (in this case the time and the number of rotations) and by displaying the results on the computer programming interface or in the small display that is embodied in the robot. Every time the engine powers and the distance traveled are modified, the program calculates and displays the new speed and acceleration.

3.5 Fifth Meeting

During the fifth meeting the students were asked to calculate the speed of a rotating rod attached to a robot wheel (whose radius was known). In order to make the task more complex, the students were also asked to calculate the acceleration of the rod. This was made to activate their critical reasoning as students had to realize that the calculation could not be done with the available data.

3.6 Sixth Meeting

During the last meeting the students created a program at their choice by using the formulas or programming blocks used in the previous meetings and choosing to work on the concepts of physics or programming.

They created interesting programs: Group 1 created a robot that calculated its length, if dragged on a surface; Group 2 created a robot able to carry out a path without impacting walls or obstacles; Group 3 made a variant of the robot that calculates the speed without using the stopwatch, but setting a timer so that the robot would stop after a predetermined period of time; Group 4 made a variant of the robot that calculates the distance, that was able to display the results of the calculations on the embodied display and keep in memory the previous measurement; Group 5 created a robot capable of recognizing the color of a spherical object and of transporting it to a particular position.

4 Discussion

During our experience, that is only a limited part of the project PROMISE, we could ascertain that ER may significantly contribute to creating a stimulating learning environment for both students and teachers.

Concernig to the students, as other studies already demonstrated, there is a particular interest towards the robots as well as towards all that is digital and technological. The observation of the dynamics that have been established during the workshop path demonstrated a strong participation by the whole class group with evident stimulation of the ability to work in group, an intense collaboration and a continuous comparison among pairs. Finally, observing the results of the last meeting, in which the students were free to create a program, we can see how the skills and abilities that were stimulated during this type of activity were extremely various. In fact, we can see that some groups have focused more on the implementation of programs that solve problems in physics, others instead have worked more on problem-solving related to the programming of the robot (i.e. to walk a track avoiding obstacles or recognizing colors), others have also focused on "engineering" aspects, such as adapting the robot body according to the task to be performed. Another significant outcome that resulted by the final interviews with the teacher is the perception of an increasing in the academic performance of the students that were usually less motivated to learning.

In general, also the teacher was very satisfied about the activity, and she wondered about the improvement in learning of her students.

More in general, we can affirm that all teachers involved in the PROMISE project have been showing a strong interest and motivation about ER. As demonstrated by the talks with the teacher during and after the internship, this type of activity improves the feeling of effectiveness of their teaching method, making teachers more motivated and improving the perception of their work status. Indeed, they not only consider robotics an excellent tool for support teaching but they also see it as a big change compared to the monotony of traditional teaching. The greater involvement of students in the topics dealt using the robots, makes the teacher's work more rewarding. It makes easier keeping the class's attention for long-term.

In the light of these results we can affirm that educational robotics is not only a facilitator for students but also for teachers. The introduction of these tools to support teaching seems to have positive effects also on the school climate and the performance of teachers within their working context.

Our aim, in the following studies and activities of the Promise Project is to sustain all these claims reporting also quantitative data, that are currently under collection.

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