Good Educational Robotics Practices in Upper Secondary Schools in European Projects

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Abstract In the fields of MINT (mathematics, ICT, natural sciences, technology), there is an increasing lack of young talent throughout Europe. It is clear that early exposure to scientific experiences is the key to motivating young people, especially girls, to develop an interest in these fields. The Erasmus + MINT “Kits for Kids” project is a current initiative for the design and production of integrated learning units as open educational resources for primary school students, of which there is a real demand. The main themes are learning media for primary education, such as simple mechanical machines, computer software, electrical appliances and related learning material. Our product, R4G—Robot for Geometry, is a device that can be used to teach mathematics, geometry and fractions. The aim is to improve performance and motivation from primary school level, using interactive and innovative teaching methods and tools. A second project, named EUWI—European Waste Investigation, is currently in progress, whose aim is to investigate water and pollution in the countries involved in the partnership.

Keywords Education · Teaching · Technology · Mathematics · Robotics · Environment

1 Introduction

It has become evident in all European countries, that interest in MINT subjects, and consequently the competences in these fields, and the number of MINT teachers, is falling across Europe. Thus, innovative methods are needed at the pre-school and primary levels, especially in the areas of science and technology [1].

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It is at this level that learning processes and individual competences must be initiated and nurtured, if future generations are to be successful in tomorrow's ever-more-technological world. It is a recognized fact in education that what we learn at an early age is more firmly anchored in our minds and can be built on successfully in subsequent learning phases. Any inhibitions that young children have, especially girls, can be reduced.

The learning units we developed in our Erasmus + MINT "Kits for Kids" project [2] are particularly innovative, because they provide playful access to science. It is our intention to assist in counteracting some of the deficiencies in the current educational situation at primary level. So far, initiatives in this field are still in their infancy, so our project will play a leadership role.

This project also helps to promote alternative learning and teaching concepts for primary schools.

2 R4G—Robot for Geometry

The idea suggested by a primary school teacher is to build a small moving/self-propelled device that can draw geometric shapes on large sheets of paper. The sheets of paper can be used to create posters to be hung on the wall, to get the children cut out geometric figures to help with memorization, to create complex geometric figures or explain other mathematical concepts like fractions.

2.1 *Mechanics*

During the first phase of the project, students in the electronics and mechanics departments of our school designed and built a prototype, using software and tools available in our school laboratories.

After the first prototype, partially created by cutting and modelling Plexiglas with machine tools, all the parts were designed in SolidWorks [3] software and 3D-printed [4]. During the project, thanks to the simple and rapid production of the pieces in the laboratory, the students were able to make changes to the drawings and optimize the products (Fig. 1).

One very important part of the device is the mechanism that moves the pen: it has to draw while the robot is moving, and stop and lift up when the robot stops.

For the second prototype, students used new motors with different characteristics, which required them to design new supports.

Later in the project, students developed a new, smaller and lighter prototype, and produced it entirely using a 3D printer.

The frame is a single piece and can contain all electronic control components (control board and batteries) (Fig. 2).

Fig. 1 First vehicle chassis

a)

b)

Fig. 2 a, b 3D frame model

One very important part of the project was the cover design. R4G robot had to be fun-looking and attractive to young students, like a toy. With this in mind, the students designed and printed two different 3D covers, R4G Turtle and R4G Ladybug, both in bright colors (Fig. 3).

2.2 Electronics

The robot's control electronics went through various phases of development which were highly educational for the students. They got to experience all the steps in design of the electronics, from rapid prototyping to engineering for small series production. The first prototype was made using several electronic boards available on the market: a microcontroller board (Arduino), and a stepper motor driver like the one used in small 3D printers. The two main bipolar precision stepper motors connected to the wheels are also from the world of 3D printers.

Fig. 3 R4G Turtle and R4G Ladybug

Fig. 4 Example of a text menu

A small servo for model-making was used to move the pen vertically. A low-cost graphic display and a 5-button keypad arranged crosswise was used as the user interface for selecting functions and modifying parameters.

The software was developed using a standard Arduino environment (IDE) [5, 6]. Some students were involved in developing various portions of the code, making ease of use a priority. Algorithms were developed for the design of squares, rectangles, triangles of different types, circles, and circular sectors. All geometric shapes could be selected via a text menu. All figures can be parameterized to generate drawings ranging in size from 10 cm to 1 m (Fig. 4).

This first prototype was successfully tested in several primary school classes (Fig. 5).

After the first prototype, given the interest and the soundness of the project idea, a second, a third and a fourth prototypes were developed. New functions were added to each new prototype, and the engineering was improved for possible small-scale production (Fig. 6).

In terms of hardware, the aim was to design a single board that would contain all the control and power components. An industrial-style PCB was created for the last prototype.

The same microcontroller on the Arduino Uno board was used for each prototype. This ensured the software was compatible from one prototype to another; therefore it was not necessary to change the development environment. Power was supplied by standard lithium batteries (18,650). We moved to low-cost unipolar motors fitted

Fig. 5 First complete prototype

Fig. 6 2nd prototype with single PCB

Fig. 7 Graphical menu

with mechanical gear reduction. The selection menu was changed and became fully graphical (Fig. 7).

A Bluetooth interface was added for interfacing with a computer, tablet or smartphone. An audio module was also added to reinforce the menu with speaking suggestions. This was tested successfully in a primary school in Germany during one of the Erasmus “MINT Kits for Kids” meetings.

2.3 Final Product and Sharing the Results

At the end of the project, two final robots were built and presented during the last meeting in Germany. Before this meeting, some of the students involved in the MINT project met two grade-four classes from “Collodi” Primary School in Ancona and showed the R4G robot to the students and teachers. The students were very interested and keen to try the robot. They tried guessing the shapes and suggested other functions and ideas for the cover (Fig. 8).

Our R4G robot took part in the European edition of the Maker Faire in Rome [7], from October 14 to 16, 2016. It competed in the section open to educational institutions in European Union countries (14–18 age group).

A jury selected 55 of the most innovative projects presented during Maker Faire Rome 2016 in an area dedicated entirely to schools (Fig. 9).

3 EUWI—European Waste Investigation

This is a new Erasmus + project, which began in 2018 and is still in progress. Three other European schools are involved in the partnership. The aim of the project is to study local waters in each of the countries involved, by testing samples, and also by creating a scuba diving robot.

Fig. 8 **a** Presentation at “Collodi” Primary School, Ancona (I); **b** Presentation at Berufskolleg Tecklenburger Land des Kreises Steinfurt, Ibbenbüren (D)

Fig. 9 Maker faire Rome—October 2016

A team of students specializing in chemistry, electronics and mechanics are working on these topics in collaboration with Dipartimento di Ingegneria dell’Informazione (DII) of Università Politecnica delle Marche.

4 Conclusions

Our students worked in groups, acquiring soft skills like problem-solving, team building, leadership, and peer cooperation. Students with different specializations shared their knowledge, thereby increasing their technical and subject skills.

The primary school students who tried the robot appreciated how easy it was to use, and learned mathematical concepts interactively while having fun.

In general, all the educational robotics experiences in our school originated from the curiosity of boys and girls. The use of robots proved to be an effective learning tool for students of all ages, ensuring they are not mere users of these instruments, but are also aware of how they function. Educational robotics enables them to identify constructive procedures to find solutions to concrete problems. It is learner-centered teaching, meaning that, instead of being passive recipients of concepts, learners learn effectively through experience, error, interaction with the environment and with others.

This type of learning is particularly productive, since knowledge comes from being active and doing, which begins with curiosity, from a question, and passes through trial and error, hypotheses, in pursuit of suitable solutions. Students will be motivated, involved, passionate because, after all, robotics is a game, a “serious game”, which stimulates creativity, the imagination, and the ability to solve problems [8].

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