A workshop to promote Arduino-based robots as wide spectrum learning support tools

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Abstract. This paper discusses the design of a workshop in Educational Robotics based on Arduino offered to fifty different classes in Italian schools, from primary school to high school. We provided different examples with two robotic platforms. We present some observations about the current conception of Educational Robotics among teachers and students and about the related problems in its introduction in schools. The paper includes a description of the proposed activities and a preliminary evaluation of the results.

Keywords: Educational robotics · Arduino · Learning support tool · Conception of Robotics

1 Introduction

This paper presents a workshop in educational robotics that is taking place this year in Italy starting in February 2016 and ending in May 2016. The workshop is the result of a collaboration between the Department of Information Engineering of the University of Padova and the Italian association Gruppo Pleiadi [1] whose mission is the scientific dissemination. The reasons behind conception and design of this project are:

1. a strong belief in the potential of educational robotics as a learning tool for the improvement of psycho-pedagogical skills and as an innovative support for traditional theoretical lessons [1,2,3,4];
2. the awareness that, despite this potential, educational robotics still plays a marginal and sporadic role in schools [1];
3. the possibility to exploit some current favorable conditions: relatively low-cost robots on the market and suitable for educational purposes; the previous experience of the involved researchers; a relevant demand of teaching/learning innovation coming from the school system and families in Italy.

Nonetheless some limitations still remain and we decided to focus especially on the two of them that we considered the most relevant:

[1] http://gruppopleiadi.it/

– the lack of resources to buy the right quantity of robotic kits for the entire classes [5];
– the reticence of many teachers, often due to the conception that robotics activities are difficult for students but also too complex for their personal competences [6,7].

Keeping these points in mind, we started the project Officina Robotica [2] willing and hoping to spread a new, different conception of educational robotics.

The workshop that we will describe in this paper is only the first step of the project and consists in two lessons of two hours each, dedicated especially to automation aspects; the planned recipients of the lessons are fifty classes of different grades and ages, with an average of 25 students for each class.

The main purpose of these lessons is to engage both students and teachers increasing their curiosity about robotics, and to convey the positive conception of robots as a powerful and amusing learning tool. In particular, we want to convince teachers about these facts:

– robotics can be addressed with different levels of difficulty, from simple to very complex;
– the presence of an artifact during the learning process increases the student engagement and encourages active learning (a concept consistent with constructivism and constructionism theories [8,3]);
– during robotic activities a teacher has a different role compared to traditional lessons: he/she is personally stimulated to find the solution/solutions collaborating with the students and not imposing ready-made solutions;
– it is possible to have an affordable but fully operational laboratory with robots, adaptable both to a computer-based lab and to the usual classroom;
– using robotics, it is very simple and natural to develop links with curriculum subjects (educational robotics does not mean to study robots in technical details).

Regarding the students, the goals of the project are:

– to convey the concepts of sensor, actuator and microcontroller, and how they interact with each other;
– to make them glimpse some practical applications of the theoretical knowledge;
– to inform the students of the existence of affordable robotic tools that can be further explored out of school.

As better explained below, for the purposes of this workshop many reasons convinced us to adopt Arduino-based robots. In spite of our previous experiences, the main factor not to use the more common LEGO Mindstorms robot for the workshop was the limited allocated time and the cost.

[2] http://www.officinarobotica.it/

2 Structure of the workshop

The workshop activity originates from the project Officina Robotica and is being developed thanks to a collaboration between the Department of Information Engineering of UNIPD and Gruppo Pleiadi.

The purpose of the activities is to introduce among teachers and students a new and stronger perception of the wide possibilities educational robotics can convey in school along with the idea that robotics is a tool accessible and ideal for all ages; the project is therefore addressed to all school levels, from primary school to high school.

Keeping this objective in mind, we presented the workshop to fifty classes among thirty different schools, located in different cities of north (78%) and central (22%) Italy, namely:

- twenty primary school classes (1st-5th grades);
- twenty junior high school classes (6th-8th grades);
- ten high school classes (9th-12th grades).

The project involved among 1250 students and 40 teachers. We selected the schools according to the order in which they have requested to participate. They were both public schools and private schools. Regarding high schools, almost all the teachers who asked to participate belonged to technical schools. The age of the students was highly variable, especially for primary school (40% of the students was 6-8 years old). Regarding junior high school and high school, among 90% of the students were 12-15 years old. Almost always the students who took part in the workshop were not voluntary but they belonged to a class chosen by the teacher.

The workshop is organized into two lessons of two hours each, with a break of a month between the first and the second. The first lessons took place from the second half of February 2016 to the second half of March 2016. The second lessons were scheduled in April 2016. For almost all the students who take part to these activities, this is the first experience with robotics and also mostly for programming.

3 The instrument

3.1 The tool: why Arduino

Arduino-based or compliant robots were our choice due to some important positive aspects:

- relative easiness of construction;
- low-cost components, giving the students the possibility to replicate experiences at home;

– a variety of usable programming environment (beyond the standard Arduino IDE [3], Ardublock [4], Scratch for Arduino [5], Snap for Arduino [6], Mblock [7]).

Arduino is specifically linked to the Maker philosophy: it is in fact especially suited to the improvement of manual skills and active experimentation. The goal is to make students reflect on the strong relation between the theoretical contents they just learned and a direct real experience, in order to lead them to think about the world in an informed and scientific way, as opposed to a "magical one" [9]. The rich set of sensors and actuators compatible with Arduino is well appropriate to this purpose. The cost-effective quality of Arduino was particularly appreciated in our case in order to provide more kits during the lessons, one for every two/three students. It is also a good premise to convince schools and single students to invest in robotics and thus to promote its wider diffusion. Our experience has already showed also its flexibility: Arduino is easily adaptable to different levels of competence and school stages; it can be used both to introduce the fundamentals of robotics/electronics and to develop more complex projects.

Concerning junior high schools and high schools, we opted for the usual Arduino hardware (Arduino UNO, with a starter kit included); the Arduino electronic board has to be assembled on a mobile platform, a choice we made with the hope to increase the students involvement by showing them a structure closer to what we observed their expectations about a robot were.

For the application of our workshop in primary schools we chose Mbot 2.4G version, an Arduino-compatible platform which presents some further interesting characteristic:

– the kit includes a set of sensors and actuators, some on board, some as additional extensions on mini-cards that makes the interaction between the robot hardware and the ambient clear, immediate, and partly referable to interactions common in human beings;
– among the other solutions, it can be controlled through a customized version of Mblock, a graphical environment based on Scratch.

Moreover it can be operated using an infrared remote controller and this makes also suitable for little children (aged 6-7).

3.2 Programming languages

One of the main issues in the realization of the workshop was the choice of the programming language and how much time to allocate to the programming part. In Italian schools basics of programming are taught only in some high

[3] https://www.arduino.cc/
[4] http://blog.ardublock.com/
[5] http://s4a.cat/
[6] http://s4a.cat/snap/
[7] http://www.mblock.cc/

schools, and we are conscious that it is very difficult to introduce programming in just two lessons; on the other hand, we firmly believe that robotics without any programming tasting loses its deep meaning, so we decided to introduce a dedicated section in order to show the fundamental role of programming in the robots' behavior.

Eventually we chose the following block-based programming environments for the different school levels:

- Primary school: Mblock (that it is based on Scratch)
- Junior high school: Scratch for Arduino (S4A)
- High school: ArduBlock

Considering that most students do not have any previous knowledge about programming, we chose to mediate heavily this part.

In junior high school and in high school we use an introductory activity (the smart lamp) to give a direct and simple demonstration. Students are first asked to replicate, on their pc, a project with an already tested piece of code for a first familiarization. In the following activities we gave them driving sheet with a support for the programming.

In primary school we make the choice to avoid so young students were challenged by programming technicalities in order to focus on the robot behavior and on command rich semantics. Therefore the experience is first devoted to design robot actions in terms of simple sequences of commands: this phase is supported by some worksheets illustrating in simple form the library of selected commands. These sequences are preliminarily tested using a body syntonic approach (the teacher or one classmate "executes" commands like a robot). Then the teacher codes the sequence using the graphical environment and the students observe if the robot precisely reproduces what is expected.

4 Activities

The collaboration with Vivigas&Power [8], which is supporting the Officina Robotica project, asked to orientate the activities towards the energy theme. We considered Arduino well adaptable to this theme.

The competences that we wanted to develop through the workshop are:

- understanding the structure of a robot and the relation between sensors, actuators and the microcontroller;
- understanding the role of the human pilot in controlling the robot through the programming language;
- understanding the fundamentals of building electronic circuits.

For the realization of the workshop we had to keep in mind that:

- many of the students do not have any knowledge in Arduino and robotics in general;

[8] http://www.vivigas.it/

– the selected classes presented a highly variability in age and probably also in level.

Therefore, for each of the three school levels, we chose to design a large set of activities different in complexity (both with regards the automation aspect and the programming aspect). In this way, we can easily calibrate any lesson depending on the level and the response of the different classes.

Anyway the first activities have the aim to make the students feel comfortable using robots, so these activities are focused on the manual building of very simple electronic circuits and do not involve any actual programming of a robot.

4.1 Primary school activity examples: "Macchina Scribacchina" and an example of activity with MBot

For primary school, the first part of the workshop is strongly dedicated to improve manual skills. For this we chose to start assembling some simple circuits using LEDs, DC motors and battery. Then children could use this knowledge to build the artifact "Macchina Scribacchina" (literally Scribbling Machine)[10](Fig.1), a moving machine obtained by assembling a plastic glass with a DC motor and four markers. The vibration of the motor is transferred to the glass and to the markers so that they leave some circular traces on the path.

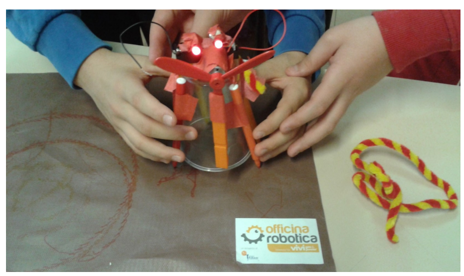

Fig. 1. "Macchina scribacchina"

After this activity, we introduced the robot MBot. The first activity was to analyze the behavior of "Nocturnal MBot". In this case, students didn't have to program the robot but only to observe the result of the program. "Nocturnal Mbot" moves only if the light intensity goes down a certain threshold. So the first impression is of a magical artifact that dances and blinks only when it is dark and we usually cannot see it [11]. In this way we want to introduce children to robotics starting from a conception of a robot close to a toy. After this first impact we go to unravel the reasons behind the robot behavior introducing a scientific explanation. The children are introduced to the sensor and actuator concepts and their role in designing a robot control program.

4.2 Junior high school activity example: the smart lamp

This is the first activity actually introducing to programming language. Keeping in mind the saving energy theme, we create a lamp that lights up only if the light intensity is low enough for the environment to be considered darkness (Fig.2).

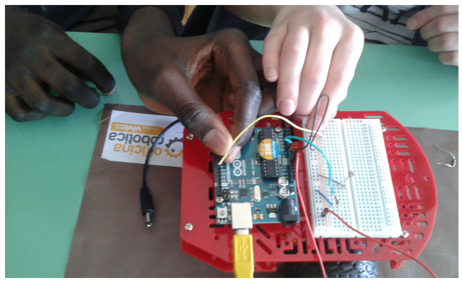

Fig. 2. Smart lamp

To realize this object, a simple LED and a photoresistor are sufficient; the aim of the activity is to introduce the concept of analog input and the necessity to understand sensor's values and how to translate electric signal into something which is understandable to humans.. The students meet for the first time some typical structures of a programming language, i.e. creation and use of variables, the if/else command, etc. The students are also encouraged to establish autonomously the threshold that allows them to distinguish darkness from light. Moreover, they are induced to reflect on the difference between the last activity, where the LED was not controlled by anyone, and this activity, where the lightning of the LED is programmed. We want to make explicitly clear that the behavior of any robot strongly depends on our given instructions.

In junior high school, after the first demonstrative phase (the students have to copy already working code), in the second part of the activity we want the pc to play a musical "instrument" using the variations of the light sensor mounted on the robot and using a little of mathematics (Fig.3). In this activity we use the

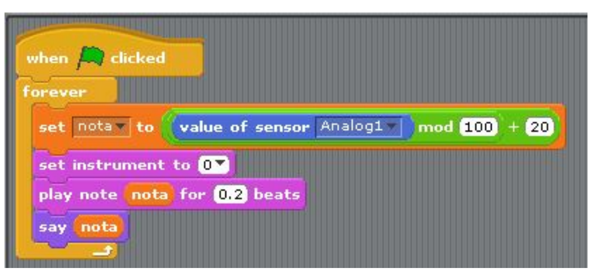

Fig. 3. Playing with the light

same circuit of the "smart lamp" and students can concentrate only on the programming part. For this exercise we give them a worksheet for the programming part, so they can reflect on it. The reaction to the outcome is very enthusiastic: the students are rewarded and they can see the potentialities of the robot. In particular, the introduction of sound elements is very engaging for students who usually present serious learning problems, giving them a chance of actively participate (e.g. choosing the musical instrument, proposing tunes).

4.3 High school activity example: ecological wake up and sunflower robot

In high school, after the introduction to programming through the "smart lamp" activity (see 4.2), we proposed the "ecological wake up" activity. The students used a photoresistor and a buzzer to create an alarm clock that starts playing when there is a sufficient quantity of light. We provided them a driving sheet for the programming and they had to complete autonomously the code. We noticed that most of them found hard to distinguish between the setup phase and the loop phase (Fig.4).

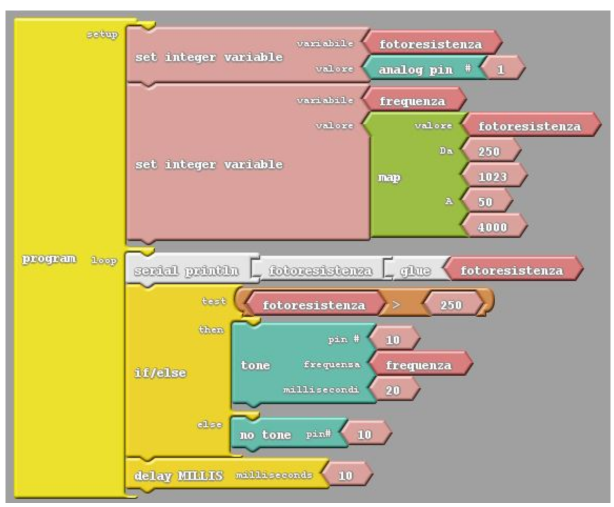

Fig. 4. An example of common error in programming

The activity "sunflower robot" will be carried out in the second part of the workshop. We create with Arduino a robot that follows a light source. This project is strongly related to the eco-save question and can be used to create a solar panel that, during the day, moves following the sun. To implement the project, we use two photoresistor oriented so that they form an angle of 90 degrees. When the light source is closer to one of the two sensors, the robot turns in order to stay in line with the source [12]. This project is strictly connected to practical needs and allows an immediate understanding about the possibilities when using robotics and theoretical knowledge in a daily context. This can be useful to improve the engagement of students and to justify the effort of the activity.

5 Evaluation of the workshop: preliminary considerations

5.1 The evaluation tool

The evaluation of the workshop will be done at the end of the second lesson, through a short questionnaire that will be issued to the involved teachers. The questionnaire aims at evaluating essentially three points:

- the conception about the potential of educational robotics as a learning support tool;
- the intention to introduce an educational robotics curriculum;
- the level of satisfaction about the workshop.

The respondents are asked to answer both to closed questions (yes/not) and open questions ("Do you think that educational robotics can be a useful support learning tool? Why?", "Do you think about introducing some robotics activities in your lessons? Why?").

Regarding the students, we considered meaningless to evaluate any improvement in learning after only two lessons. Therefore, we preferred to give them the opportunity to elaborate and to reflect about the recent knowledge through a contest, that is to design a robot with the purpose to help the ambient, using strongly the concepts of sensors, actuators and energy in general. In junior high school and high school, students can present an original project using an hardware like, for example, Arduino and LEGO Mindstorms, or a report of an activity of the workshop. Instead, in primary school, students can simply describe and draw the imagined robot. A contest is not an evaluation tool but, using a contest, we would like:

- to have a general feedback about the understanding of the conveyed concepts;
- to induce students and teachers to carry on a part of the workshop autonomously, without the external intervention.

To encourage the schools participations, we reserved a prize for the best project (a kit of five Arduino for secondary schools and a kit of five MBot for primary schools).

5.2 The role of the (curricular) teacher

One of the greatest problems we met introducing robotics during this workshop was the rapid demoralization of students when they face a failure (especially at junior high school and high school). This is probably due to the fact that many of the arguments are introduced *ex novo*, but it could also be closely related to the different learning approach of robotics compared to traditional lessons. In particular, at the beginning students show a strong resistance to the trial-and-error approach that is underlying to educational robotics: they seem to be afraid of the possibility to search for a solution by themselves (they often ask the teacher for support even before making any attempt to solve the task) and most of them don't seem interested in spontaneously exploring new solutions, unless the teacher compels them to do it. This is particularly evident in female students who sometimes appear less engaged in the subject.

In view of the above, we consider the role adopted by the curricular teacher fundamental for the positive involvement of the students [13,14]. The teacher in such a constructivist learning approach like the one described above does not work as a teacher - authority that transfers ready knowledge to students - but rather acts as an organizer, coordinator and facilitator of learning for students. He/she gives the guidelines of the activity, provides to students with many materials for thoughts and observes their learning process. His/her presence should be very discrete and his help should be offered only when necessary. He/she should allow students to work with creativity, imagination and independence [15]. Acting like this, the teacher should:

– encourage the students to adopt an active role in the learning process, based on direct experience without fear of making errors;
– help to build their self-confidence, trying to make them feel that his/her help is less crucial and the stepwise refinement of solutions through a trial-and-error process is the main guideline.

Finally, in order to increase their involvement, the teacher has to mediate the meaning of the experience underlining both the links with reality and the connection with the theoretical knowledge learned at school; in this way he/she realizes a mutual contribution amongst robotics and theoretical lessons aimed at increasing the students' interest.

5.3 Preliminary results

Until now about ten classes have completed both the two lessons, but we can anyway make some preliminary observations about the achieved goals.

In general, our perception of the project's outcome is positive. Due to the diversity of the involved schools and classes (grade, number of students in each class, participation of the teacher), we can observe a dfferent feedback regarding the robotics conception that we try to convey. Of course in classes with a large number of students (more than 25) it can be hard to take on such a workshop: numerous requests of help and support can concurrently come from dfferent groups and this would suggest the presence of more tutors. The risk of that is to observe a certain degree of discouragement. Even if it is not surprising, we registered the more enthusiastic feedback in primary school (especially in students), while junior high school confirmed as belonging to the most critical range of ages (in particular it resulted more dfficult to design activities with the right level of complexity using Arduino).

Regarding students, in general we noticed a sincere enthusiasm, despite some difficulties (see 5.2); moreover some of them seemed to be interested in the possibility to carry on autonomously the activity out of the school. Regarding teachers, we perceived an high appreciation as well. This confirmed by the partial data obtained by the questionnaire. On the basis of the opened questions and

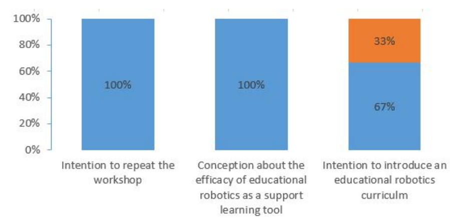

Fig. 5. Partial results from the questionnaire

other general observations, it results that the good level of satisfaction is due especially to:

– the engagement of their students in using robots;
– the awareness that educational robotics takes advantage of diverse skills, which don't usually come up in traditional education. In particular, they pointed out that in many cases, among the students that better succeeded in the activity, there were surprisingly students with an otherwise low school performance.

However, despite this positive reaction, several teachers revealed they are not intentioned to introduce educational robotics in the curriculum because they are not confident of their competences (Fig.5). Also among the teachers that said yes to this question, most of them declared to not feel able to do it without an external support.

6 Conclusions

At the moment of writing, all the fifty selected classes have already taken part in the first meeting of the workshop and about ten classes have taken part also in the second meeting. All the schools involved in the workshop asked voluntarily to participate, often due to a specific interest of teachers qualified in scientific subjects. In general, our perception of the project's outcome is positive: after an initial resistance, most students felt rewarded by the results and seemed impatient to continue the experience with a next lesson. The feedback of the involved teachers was positive, as well, and, in particular, their conception about the potential of the educational robotics as learning support tool seemed to be increased. Despite this, most of them not yet feel able to carry out autonomously educational robotics activities.

A more complete evaluation of the workshop will be done after the end.

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