The development of robotic-enhanced curricula for the RoboESL project: premises, objectives, preliminary results

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Abstract. The paper describes the design, development and implementation of the first five robotic-enhanced curricula which are the basis of the Roboesl project. It also includes some premises that justify the use of educational robotics to contrast the ESL phenomenon. Each curriculum is presented in sufficient detail to explain motivations and objectives. The two training activities held so far, i.e. the two courses for teachers of the partner schools as trainees, are also briefly presented.

Keywords: Roboesl, Educational robotics, Mindstorms EV3, Teacher training, Early school leaving

1 Introduction

The RoboESL project ('Robotics-based learning interventions for preventing school failure and Early School Leaving' - roboesl.eu) is an Erasmus+ key action 2 funded project dedicated to the development and experimentation of robotic-enhanced curricula aimed at providing new engaging activities in the class. The final goal of the project is to reduce the risk of Early School Leaving (ESL) and more generally to stimulate interest in students with some weakness. The project includes three main subparts: (1) the development of curricula for ten exemplary interdisciplinary robotics projects, which is the main content of this paper; (2) a curriculum for blended training courses for teachers, based on constructivist pedagogical approaches; (3) the implementation and evaluation of the proposed robotic projects within extracurricular activities involving sample groups of students of the partner schools in RoboESL.

Educational robotics (ER) has been proved as a powerful tool for promoting project-based learning, computational thinking, peer education, team working, learning by doing, inquiry based education [1, 2, 3]. Involving students in activities with a practical part and applying constructivist/constructionist approaches leads to teaching/learning processes that increase students' self-esteem and make them think more easily that a life-long learning is a no more avoidable requirement for their future activities and success [4].

Our previous experiences and work were essentially addressed to medium level students and a specific attention was put essentially to the general 'low threshold, high ceiling' principle, that is an approach that, without limiting excellence, is accessible to most of the students, independently of their level and ability. ER as a teaching/learning tool provides these characteristics. When ESL is concerned, the perspective changes and more attention must be reserved to the accessibility of the proposed projects in order to fulfill the main objectives of the research. Apart from students with permanent special needs, either cognitive or physical or both, needing a specialized support [5, 6], students at risk of ESL are a broader, and even increasing, percentage of the total and the problem arises from different, maybe temporary, premises. Here a citation of the RoboESL project document:

Early school leaving is a long process of school disengagement closely connected with school failure. Research studies show that drop-outs are students with low achievements or failure in one or more school subjects, very often in science, technology and maths. Rarely a single factor lies beneath ESL.. . . Educational content is boring or hard to grasp, activities are not related to real life, practical tasks are missing, and opportunities for hands-on activities are not given.. . . There is a gap between the current educational practices in schools and the modern societal needs calling for an education that will foster creativity and inventiveness.

Some intrinsic aspects of ER seem to satisfy the abovementioned requirements: engaging, related to STEM and possibly to STEAM, funny and easily satisfactory, practical, related or easily associable to real life, easily designed in terms of hands-on activities, fostering creativity and inventiveness [7, 8]. Nonetheless special attention must be dedicated to the initial impact that robotic labs can have on weak students: all those aspects that can offer difficulties or be perceived as complicated must be smoothly introduced in order to make the students acquainted with this technology. Among these aspects we would mention complexity in robot building, programming, subtle mathematical aspects. Of course the point is not to avoid any kind of cognitive challenge, but to calibrate such challenges in order to transform problems and their shareable practical solutions into vehicles of new interests and enthusiasm.

The design of the new curricula has been inspired by these general concerns: they are organized in a ordered sequence so that the first ones are simpler and propedeutic to the others. The following section gives more details about the approach adopted in the design of the robotic projects, while section 3 briefly describes the projects designed so far together with some details about their implementation. Section 4 is dedicated to a summary of the training activity held during the two training sessions organized within the project. The final section contains some conclusions.

2 The design of the robotic projects

When you design robotic-enhanced activities, you must take some initial strategic decisions depending on the level of school, the specific characteristics and requirements of the class, and your educative objectives. These decisions regard the robotic platform(s), the programming environment(s) and the sequence of projects you want to explore with your students. All these aspects have an impact on the degree of acceptability and effectiveness. In the RoboESL project we considered the positive experience we had previously with the Lego Mindstorms platform and its iconic programming environment and we were all convinced that this solution would have been suitable for attracting weak students and making the project accessible to them. More specifically, regarding Lego robots we positively considered these aspects:

- Students have often a previous knowledge of the building approach of Lego kits, with a calibrated degree of complexity; this can help to start the construction of simple robots without a high initial barrier;
- The possibility to start with very simple constructions but, at the same time, the absence of a practical limit to increase their complexity with a progression which is aware of the real cognitive potential of the class, is a good premise for designing an affordable and effective sequence of projects;
- Lego robots manifest all the multidisciplinary essence of educational robotics, they are relatively robust and easily extensible, and not very expensive with respect to the reachable precision and variety of available sensors, either included in the kit or bought separately, available also from third parties;
- The aesthetic of the robot and of the scenario where it acts can be profitably designed to promote interest in artistic aspects;
- A Lego robot includes accessory features such as sounds, lights and a display, in addition to other possible extensions to be connected through the available output ports, which make the built object particularly attractive and funny;
- The icon-based programming environment, together with the possibility to define user blocks (this is a precondition for the teacher to provide a personalized version of the environment though a user-defined block library if, for example, she wants the students to start with a simpler set of basic blocks), assures a low initial threshold in the implementation of the control software; moreover the current version of the environment is easy to understand and enriched with useful helping features.

For all these reasons we are applying our experimentation on this kind of robots, but at the same time we have the goal of providing exemplary projects which are not strictly depending on the Lego ‘ecosystem’. This means that, at least partly, the designed projects should have been implementable also on other robots, provided a common set of available features like: controllable motors, touch, light and ultrasonic sensors. This assumption makes it possible to adopt even cheaper robotic platforms, like the ones based of Arduino or Raspberry cards.

The second relevant point on the design is how to calibrate the progression of exemplary projects to fulfill the following requirements:

- all the projects must be contextualized (i.e. they must not be an end in themselves); the contextualization should refer to real life situations where the robot can play a role either as a robot for itself or as a simulator/emulator of a machine, an animal, a human who are part of the proposed scenario. Links with diverse disciplines must be created. We provided a set of suggestions that the teachers can extend and integrate to foster the passion and the interest in her students and to create links with other disciplines. This aspect is significant for pedagogical approaches that we want to exploit in our project, like situated learning [9] and constructionism [3, 10];
- the chosen context should lead to the definition of variants of increasing complexity to permit a certain degree of variability and extensions in a

constructivist perspective; this allows the teacher to adapt her proposal to specific needs of the class and to help her to find other suitable variants without a big effort;

- programming blocks are introduced progressively when their necessity is easily understood by the learners: consequently, the teacher is helped to justify their introduction and the students' comprehension is improved by the inquiry attitude that can be promoted during the experimentations;
- the progression of examples must start with a very simple task, but the general principle that any step provides new knowledge useful to afford next steps, must be always present;
- all the projects should stimulate team working and a balanced synergy of personal attitudes and contributions of the students in each team.

All the presented general requirements are taken in consideration for the development of the promised curricula; this is under the specific responsibility of our unit at the University of Padova (Italy) but all the other partners collaborated in form of preliminary ideas, suggestions during the development, preliminary verification and testing.

3 An overview of the projects

In this section we briefly present the first five developed and tested projects. From this presentation the reader can have a clearer idea of the designed progression and it is also an excuse to add some interesting comments. Though in these projects the robot construction is not particularly in evidence (in fact all these projects can be implemented building a basic tribot structure), as already emphasized, the aspect of the manual building of the robot is important and the teacher can experiment other layouts of the robotic platform to furtherly engage the students or, if considered appropriate, even to simplify the building phase.

3.1 The Roborail

This first project represents the emulation of a monorail vehicle (Fig. 1), similar to those you can find in big entertainment parks or in futuristic transport lines. The robot, starting from an initial position, has to follow a straight line which 'contains' a total number of S stations (S-1 subtracks) at fixed distance between one another: apart from unavoidable initial acceleration and final deceleration, it has to move with constant speed from one station to the following one, waiting for some seconds at any intermediate station until it reaches the final one where it eventually stops, terminating the program[1]. The contextualization and the connection with the real life are evident; interesting links with geographical and historical subjects are also easily detectable.

[1] A first example of possible extension of this first simple project is to challenge the student to repeat the trip backward and then to repeat the trip back and forth indefinitely.

This is a paradigmatic example of the so called ‘straight-line robots’, very simple vehicles able to move back and forth on a straight path. This class of robots permits to limit the complexity both of the construction and of the controlling program, to the point that it would be sufficient to mount a single motor connected to a pair of drive wheels to make the robot move linearly, neglecting inherent inaccuracies avoidable only by imposing the motion on a real rail. This simple motion does not require sensors in the simpler variants, apart from the rotational sensor which is implicitly integrated in the wheels and allows to precisely control their rotation.


Fig. 1. The Roborail.

In spite of its simplicity, this first experience is designed to be useful to introduce some important basic commands of EV3-G (the graphical environment) and to provide several hooks to develop themes related to science and technology, stimulating interest in these subjects through simple reflections dealing with time, space, speed, wheel rotation. The introduction of a geometric model is possible though not immediately compulsory: the tuning of the robot motion can be done through a trial-and-error procedure or exploiting a simple relation of proportionality once established a reference motion (for example, measuring first the space spanned with one complete wheel rotation).

The control software for the basic variant is very simple, nonetheless it gives the opportunity to introduce very important blocks (*Move steering (straight line form)*, *Wait (for time), Loop*) which will be again useful for the next projects. The teacher has also to calibrate the number of detailed information to transmit to the students, applying the general principle that it is more effective to introduce some new aspect when it is perceived as necessary to solve a problem.

Suggested extensions to the project are: adding sounds (and therefore the *Sound* block), establishing random speed for every track (this time with the new *Random* block), forcing lower speed in a specific subtrack (this makes necessary a *Switch* block), indicating the position of a stop with an obstacle recognized by an ultrasonic sensor on the robot or by means of a marker sensed by a mounted light sensor (with the necessity of using a new block variant, *Wait on sensor*), defining parametrically the distance between stations (this is an excuse to introduce variables). In addition, all the projects can suggest the definition of user blocks: presenting at the right moment the technique to define a user block in the EV3-G programming environment is a powerful tool to promote abstract mental processes which can help to face a (relatively) increasing complexity.

3.2 Go to park

The scenario of this curriculum, a parking area with N equivalent slots on one side (Fig. 2), represents a known situation and therefore the comprehension of the scenario in which the robot has to move and turn is straightforward. Moreover, the activity can be framed in the current trend on autonomous driving. Students can be challenged to design an autonomous parking behaviour for future cars. In this case, we suggest to perform the turning of the robot keeping the internal wheel still, the so called 'swing turn' (Fig. 3). The vehicle has to orderly check which is the first empty slot: this is done moving first in front of the slot, turning 90 degrees and checking by means of the ultrasonic sensor the presence of another vehicle already occupying the slot. If the slot is empty the robot goes inside it to park and trumpet a triumph sound, otherwise it turns back 90 degrees to move to the following slot. If it finds all the N slots occupied, it 'complains' by playing a awkward and sad sound, then it stops.

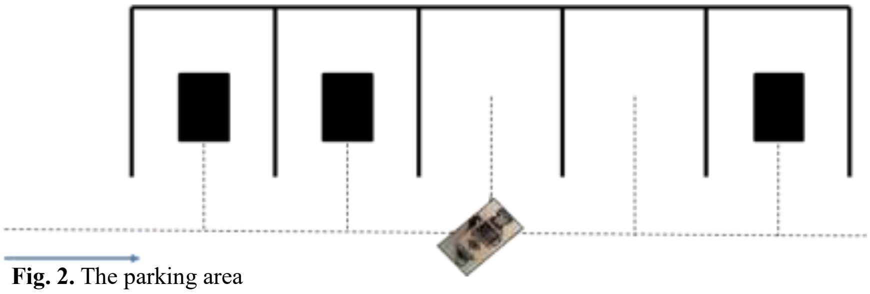

Fig. 2. The parking area

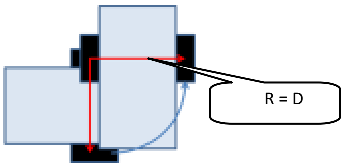

Fig. 3. Swing turn

This scenario leads to several interesting discussions around modern automotive technology, safety issues and the geometric problem to turn the robot by a certain amount of degrees. Keeping one wheel stopped means that the radius of curvature corresponds to the inter-wheel distance (*D* in the figure) but the angle spanned by the robot depends also on the wheel radius *r*. Thus the students are invited either to experimentally evaluate the correct rotation of the moving wheel or to discover the geometrical model which represents the ideal turn of the robot. In both cases they can step by step discover the relatively simple relationship between such rotation and the angle of turning, that is proportional to *D/r*.

This curriculum gives the teacher the opportunity to introduce some new commands: *Variable*, *Move tank* to control the two wheel speeds separately, *Count loop* (N is known from the beginning) and *Switch* which permits to differentiate the robot behaviour according to the state, free or occupied, of the checked slot. Major proposed variants are: parking in the last empty slot, which is a sort of search of maximum in a list; use of the ultrasonic sensor to sense the unknown slot width; a more automated parking.

3.3 The desert scout

The hypothetical scenario of this third curriculum is an autonomous robot for discovery of new gas fields in a desert. The mission of the robot is to core the desert ground at several spots and to report the most promising spot where to dig a gas well. Imagine to be in a large desert where you know that you can find gas fields all around. An automated campaign is designed to perform the corings on the vertices of a regular hexagon of suitable size. The robot has to make these measurements and to report the position of the vertex which reveals the best field. This is the hypothetical scenario of this third curriculum. In order to simulate the situation, the robot starts from one vertex, the docking station, and follows the successive hexagon sides. The measurement on each vertex is represented by the color code of a marker (Fig. 4).

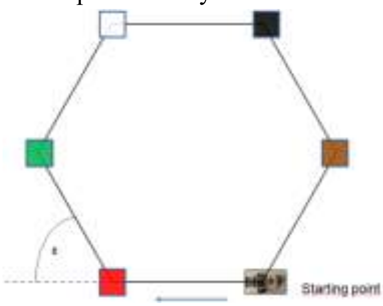

Fig. 4. The scouting path

In order to maintain the alignment with the sides on each vertex, the turn must now be performed so that the centre of curvature is on the middle point of the segment ideally connecting the two wheels: this means that the wheels must be moved in opposite directions and with the same absolute speed, a type of turning which is called ‘spinning’ (Fig. 5). Therefore the students must adapt the results obtained during the previous curriculum to the new requirements, though the geometrical model is not much more complicated. The scouting of the maximum value of the color code is made possible using the color sensor and its homonymous command: maximum value and its position in the polygon are stored into two variables whose contents are displayed as the final operation when the robot comes back to the docking vertex.

Again this curriculum gives the opportunity to introduce new interesting commands, like *Color sensor*, *Display*, *Compare*, *Math*, *Text*. Spinning is produced with a *Move steering* command with maximum steering factor (100); the robot angle is set according to the external angle of each vertex of the hexagon. Notice that, after these first three experiences, students can be asked to define the four basic personal blocks necessary to simulate a floor turtle (forward, backward, left, right).

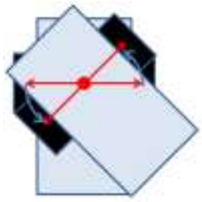

Fig. 5. Spinning

3.4 Let's play and dance

The attractiveness of a curriculum is also based on some funny or unexpected behaviours. This curriculum aims at transmitting such a feeling during the experimentation. The scenario is the following: a theatrical stage initially entered by the robot through a guided path (line follower) and then a sort of dance synchronized with the 'music' produced by the robot itself. The introduction of a musical component is a good excuse, for example, to mention technical aspects like frequency (musical pitch), duration, musical temperament and others. There are also interesting links between this scenario and the concept of automatic theatre.

The first part of the curriculum can be solved with a simple solution for making the robot follow the separation between a light background and a dark strip: a couple of steering motions in opposite directions within a *Switch* controlled by the color sensor and continuously repeated. A more advanced solution would require a real feedback control in order to obtain a smoother behaviour.

The second part can be solved in form of a random dance: in a loop the *Sound* command generates sounds of the same duration but random frequency within a reasonable range of values, while a *Move steering* command moves the robot for the same duration but with random steering values, giving the impression that the robot dances following the music. The curriculum offers a sequence of improved variants which exploit all the commands introduced so far.

The last variant suggests a new approach: to use a file for coding sounds in arbitrary sequences, i.e. the possibility to code a generic song reproduced by the robot. The input file contains octave, letter and duration for each note of the sequence to be reproduced with a *Sound* command. The letter can also be extracted from the file and used as the parameter of a multivalues *Switch*, adopting its *Text* input option, to produce different motions for every note type, showing a more likely dancing.

3.5 The sunflower

Heliotropism is a known phenomenon which regards several plants and it is a good argument about Nature to be explored. It is not difficult to make a robot follow a light source by putting one or, better, two color/light sensors in front of it (Fig. 6). When the robot has such a 'stereoscopic' view, the difference and the average of the two values given by the sensors can be used to evaluate the distance of the light source and its lateral position. These captures are used to control the robot position in order to keep it in front of the source and at a certain distance.

Fig. 6. A 'stereoscopic' view

If you ask a student to keep a torch or another light source in one hand and move it around, the robot automatically moves simulating heliotropism. If you mount just one sensor on the robot, it is easy to keep the distance but it is much more challenging to keep the correct direction due to the lack of information: in fact the robot should turn left and right to perceive the lateral position of the source.

4 The teacher training phase

The general principle of training teachers like students because they 'will teach as they were taught and not as they were told to teach' [11], was applied also in the occasion of this project. Two training phases were organized so far: one in Athens in February and one in Riga in June 2016. The first training course preceded the first implementation in classroom in the involved schools in Greece, Italy and Latvia, whereas the second was held after this implementation. In Athens we presented the first three curricula while the following two were reserved to the presentation in Riga.

All the teachers came to the first course without any previous experience in ER. For this reason we started asking them to work in groups and to build a robot for each group following some printed instructions to speed this process up. Starting from scratch is important to make students recognize the materials they are going to use and appreciate a making phase for preparing the more suitable platform for the successive experimentations. Taking into account the training purposes of the course, we asked the trainees to build a *tribot* that can be profitably used for the first three curricula. Building a robot with a flexible kit like EV3 is a good way to appreciate the robustness and the variety of possibilities it guarantees.

Before presenting the proposed curricula, the trainees were taught how to implement a simple *line follower* robot because, in our experience, it is a way to promote an initial interest with an example which requires a few commands but shows immediately a sort of 'intelligent' behavior of the robot.

During the presentation of the curricula, we explained to the trainees their specific didactical motivations, but this was always supported by the practical activity with the robots. This was particularly important to check the validity of the ideas from which the design was conducted and to reveal critical aspects and doubts deserving more attention. The trainees were also informed about the way to organize the evaluation of the activities with the students they would have organized in the following months. The second training course was the occasion to collect important feedback from the field and to discuss possible improvements. The two further curricula were also presented and experimented.

In both courses, we decided to organize a short workshop using an Arduino robot with the purpose to compare the difficulties and potentialities of a relative complex architecture like Lego Mindstorms, with the easiness and also some limitations of a simpler architecture like the Arduino one. As much as possible all the curricula will be also implemented using such platforms in order to demonstrate their generality.

5 Conclusions

The Roboesl projects strongly relies on the potential of ER as a means to recover the interest of weak students towards studying particularly, but not exclusively, scientific disciplines at school. The involved teachers must be first convinced that ER manifests this potential and this conviction can be only sustained by a suitable training and by their personal experience with robots in the classroom. The development of the remaining curricula will take advantage of the suggestions coming from the trainees who are now more acquainted with the robotic platform and its practical possibilities.

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