

An innovative approach to School-Work turnover programme with Educational Robotics

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Abstract. This paper presents an innovative approach to alternating School-Work turnover programme based on Educational Robotics and on project-based learning. At the beginning of the year 2017 (from January to April), Liceo Volta-Fellini of Riccione proposed a STEM practical activity to its own students as a School-Work turnover programme. This course of Robotics was developed and designed by TALENT srl and Università Politecnica delle Marche with 3 objectives: raising interest in STEM education, giving the opportunity to students to learn to work in team, raising awareness towards their own cognitive processes and capabilities through the evaluation of their experience in the alternating school-work programme. Six classes were involved in the project, three from Scientific course and three from Applied Sciences course. The achievement of the project's aims it was evaluated collecting data from students using a self-assessment questionnaire.

Keywords: VET, Educational Robotics, alternating School-Work Programme, STEM Education, Lego Mindstorms EV3, Arduino BYOR.

1 Introduction- State of the art

A key to economic growth and social well-being is to provide citizens with specific occupational skills in professional, managerial and technical jobs, in expanding fields. Many countries in the world are focusing on examining the vocational education and training (VET) systems to ensure that they can adapt to the fast-changing needs of both society and economy and that the work-related skills are delivered effectively [1]. The place where skills and guidance are mostly offered is school. The education system, in fact, has the responsibility to guide students during their first years of life, providing skills and knowledge, but that doesn't represent all that school can do for them. Schools, supported by policies established by governments, can facilitate the transition between educational levels or different types of education. Almost all countries in Europe have been developing and introducing such policies and Italy makes

no exception [2]. Firstly, the upper secondary school reform in 2010 provided a coherent and flexible framework of pathways in general, technical and vocational education. Lastly, the school reform introduced by the law 107 of 2015 (La Buona Scuola) established a compulsory alternating school-work programme for all learners in the last three years of upper secondary schools: 200 hours a year in general education (Lyceums) and 400 hours a year in technical and vocational schools [3].

To link secondary education better to university programmes and to future jobs, schools can offer optional subjects that may be useful for further learning, especially if they provide digital skills. School should also implement strategies to tackle the mismatch between the job offered and the job sought and, by doing so, facing the issue of unemployment. This necessarily implies that schools should be open to the territory and that the territory should take charge of students to make them more aware of their future choices [4].

Within this framework, the present paper aims to illustrate an experience occurred at the school Liceo Volta-Fellini in Riccione, where the compulsory alternating school-work programme took place from 09/01/2017 to 11/04/2017 and delivered a number of concepts and practical experience to prepare its students for the world they will be facing in a few years. This experience involved classes from two different background: 3 classes from the scientific curriculum and 3 classes from the applied science curriculum. Two phases were designed to provide an overview of future job possibilities: a training course delivered by TALENT srl and a guided tour to Università Politecnica delle Marche.

The activity consisted of a 12 hours training period based on Educational Robotics (ER) for both classes III and IV, from both scientific curriculum and applied science curriculum. Different tools were planned to be used: Lego Mindstorms EV3 kit was used by the students from the scientific curriculum as they had no previous knowledge on circuits, assembling hardware and programming software, while the Arduino BYOR platform was used by the students from the applied science curriculum, because they had previous knowledge of C programming language and circuits.

ER was considered as an eligible choice to realize this project because of its potential to involve student in an engaging activity capable of raising interest on technology, developing the 21st century skills [5] and providing a hands-on experience on the interaction within a group working with different roles for a common goal [6-7].

All over the world there are many examples of ER in different frameworks, i.e. in formal [8] and non-formal education [9] and at different levels of education or age [10]. Focusing on secondary education we can find examples of ER to motivate high school female students [11], that is an open issue which has not been fully addressed by policy makers and society at large yet. Tools, methods and activities, developed during the past years to introduce ER into secondary schools and other environments, have been evaluated both qualitatively and quantitatively by the scientific literature [12,13], even though they cannot be regarded as a completely exhaustive set of studies yet [14]. Robotics is a multidisciplinary science due to its own nature, and ER is no different. In fact, it is a versatile tool to teach and learn different subjects. The most investigated subjects by means of ER in Secondary school, apart from Robotics itself, are physics and maths [13],[15].

We can find examples of ER programmes to help students to choose for their future [16,17]. In particular, these last two experiences are important to the present paper because they are two Italian projects and they face the school-to-work or school-to-university transition: the first one uses ER to help secondary school students to choose between all the possibilities that the academic world offers the Computer Science curriculum [16]; the second one advocates for, and realise, a more focused training on Robotics at the completion of the school career in advanced technologies to link vocational and secondary schools to gain access to high-technology jobs [17].

Bearing in mind these useful experiences in the field of ER, a whole new project was designed based on the experience of the innovative start-up TALENT srl and the expertise of the Università Politecnica delle Marche (UnivPM). Activity and assessment were shaped to target three main objectives:

- raising interest in STEM education and related careers;
- giving the opportunity to students to learn to work in team, developing the 21st century skills;
- raising awareness towards their own cognitive processes and capabilities (metacognition) through the evaluation of their experience in the alternating school-work programme.

In the following sections, we will provide more insight on the activities and the results of the project. In Section 2 we will describe more thoroughly the planned activity and the methodologies that underpin the educational approach used. Section 3 will provide a detailed description of the evaluation methods of the results of the assessment. Results will be presented in relation to the three main objectives stated before in Section 4. Lastly, in Section 5 we sum up the whole project to make final considerations.

2 Implementation

2.1 Educational Approaches

The underlying pedagogical approach in the project is that of Constructionism, a learning theory suggested by Seymour Papert [18] on the basis of the work of Jean Piaget. The learning approach is a construction and re-construction of mental representations more than a transmission of knowledge. An effective learning takes place with the usage of manipulative materials (cognitive artefacts), which enter into a construction activity of a meaningful product. In this activity building knowledge is the natural consequence of an experience of creation, experimentation, direct observation of the effects of the actions of one's own and sharing ideas in a highly motivating context. From this point of view, technology and innovative learning environment allow students to give better chances to learn. The project was inspired by this approach both for the building of a meaningful product by the students, a robot they could creatively customize, and for the creation of programs with the aim to obtain desired behaviours of the robot (obstacle avoidance, line following etc.). The educa-

tors did not propose standard solutions for the problems during the course, but each group of students could seek for a personal way to solve the challenges.

Another approach used to design the activities was the project-based learning, an educational strategy for designing learning environments, characterized by a peculiar emphasis on the cooperative research of feasible and effective solutions to a starting problem, involving systematically new technology and trying to produce real and tangible products as an outcome of the activity. This approach is based on “learning by doing” philosophy [19,20,21] and on theories oriented to promote different learning styles and “Multiple intelligences” [22].

Peer tutoring is another useful technique which use technologies to teach in classroom: some students will be facilitators in the learning process to help other students of the same age or younger.

2.2 Description of activities

The School-Work programme was characterized by 6 lessons, each of which was marked by a different issue:

- 1- Introduction to Robotics. How to turn on robot motors. What is the open-loop control.
- 2- How to use a sensor.
- 3- How to find the line. What is the feedback control.
- 4- Follow a line with an ON-OFF controller.
- 5- Follow a line with a Proportional controller.
- 6- Obstacle avoidance during the line following.

At the end of the project all the classes went to Università Politecnica delle Marche for visiting robotic laboratories and exploring the possibilities of the academic world.

The technological lessons were designed in accordance with UnivPM and delivered by TALENT educators with the support of an internal teacher of the school. During the first meeting (Introduction to Robotics), it was presented to the students the final objective of the project: to realize a robot able to follow a black line on a white canvas. Some videos of line-follower robots were showed, to demonstrate the several fields in which it is useful to adopt this robotic solution (industrial robotics, service robotics etc.). Later, students were divided in teams composed of 3-4 people, and roles were defined: the **designer** (responsible for the project and coordinator of the team, the person who has the task to communicate to the others building instructions of the robot), the **warehouse worker** (responsible for the robotic kit, the student who has the task to look for the Lego/Arduino pieces inside the box), the **technical-assembler** (responsible for the robot assembling, the student who has the task to build the robot receiving instructions from the designer and Lego/Arduino pieces from the technical-assembler), and the **validator** (responsible for the check of the robot assembly, observing the instructions on the computer). After constructing the robot and after a brief introduction of the programming features of the IDE selected (Lego Mindstorms EV3 Home Edition or Arduino IDE) a first challenge was proposed to the students: turn on the robot motors to cover a given distance. In this way, TALENT educator could introduce the concept of Open Loop Control, indeed students solve the

problem thanks to geometric consideration (circumference formula) and without using any sensor.

The second lecture was about “How to use a sensor”, in particular the ultrasonic sensor. Each team had to program the robot to make it stop at a given distance from an obstacle, and then to make it avoid obstacle continuously.

During the third lesson (How to find the line. What is the feedback control) students approached the problem initially stated: to follow the line. The first step they tried to fulfil was to look for the line (with the robot positioned in a “white area” of the canvas), using the light sensor (contained in Lego Mindstorms EV3 kit) or the line tracking sensor (not contained in Arduino BYOR kit, but bought separately). Acquiring data from the sensor allowed them to decide what instructions to give to the motors (turn on/ turn off). In this way, TALENT educator could introduce the concept of Feedback Control, indeed students were able to set commands for the robot motors thanks to the output of the system (values measured by the sensor).

The fourth lesson (Follow a line with an ON-OFF controller) was characterized by the implementation of a simple algorithm for the line following: after having recognized the mean value between black and white, students could create a program with an approach of this kind:

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If “value read by the sensor” > “mean value”
  Then Turn right
  Else Turn left
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During the fifth lesson (Follow a line with a Proportional controller) students tried to create an algorithm that adjusted proportionally the position of the robot, depending on the error calculated as the difference between the desired value and the value acquired by the sensor.

The sixth lesson was characterized by the implementation of an algorithm that combined the proportional controller with the ultrasonic sensor, to avoid obstacles during the line following task.

3 Evaluation methods

A self-assessment questionnaire was prepared to assess the results achieved bearing in mind the objectives stated at the beginning of the project (see Section 1). Students received this final self-assessment questionnaire at the completion of all the hours spent on the project. This tool addressed two purposes: first, it assessed the appreciation students had of the activities; second, it engaged learners in a metacognitive activity, because they were stimulated, not only to think about the knowledge they learnt, but also to the process they employed to acquire the knowledge. . It stimulated, in fact, the reworking of the activities and the recognition of some personal psychological dimensions and of some aspects of the working process. Questionnaires were also supposed to find out the level of interest and satisfaction with the lessons, the relationship with proposed technologies, the relationship with educators and the relation between pupils.

We proposed a 5-point Likert scale through which students could express their level of agreement [23].

Questions were:

- Q1 - Did you understand correctly the instructions the teachers gave you?
- Q2 - Was the educator attentive and helpful when you asked him something?
- Q3 - Were the lessons proposed by the educator engaging?
- Q4 - Was it easy to build the robot in class working in your group?
- Q5 - Was it easy to use the software while working in your group?
- Q6 - Did you willingly attend the activities of the course?
- Q7 - Was the mood in the class calm?
- Q8 - Was the teamwork characterized by collaboration and support?
- Q9 - Did the relationship with one or more classmates improve?
- Q10 - Did you find fascinating this kind of alternating School-Work programme?
- Q11 - Do you like to attend new advanced course about Robotics?

These closed questions were organized around these three topics (related to the three main objectives stated in section 1):

- raising interest in STEM education and related careers; Q1, Q2, 3, Q6, Q10.
- giving the opportunity to students to learn to work in team, developing the 21st century skills; Q7, Q8, Q9.
- raising awareness towards their own cognitive processes and capabilities (metacognition) through the evaluation of their experience in the alternating school-work programme. Q4, Q5, Q11.

The questionnaire contained also four open-answer questions; these were intentionally written in a not directive form to motivate students to express opinions, observations and also critics about the experience in a free way and to gather other qualitative information. The four questions were:

- What did you learn in this programme?
- What was the thing of the programme you liked most?
- Do you think something didn't go right?
- Is there something more you would have liked to do in the programme?

4 Results

The following bar graphs describe the scores (in mean values) given to the questionnaire by students at the end of the programme. The 11 items were organized in three main dimensions that correspond to the objectives of the study (to measure the appreciation of the School-Work programme, to strengthen the team work, to increase interest toward STEM).

The first bar graph (Fig. 1) represents the mean values of the responses to the 11 items – grouped in the 3 dimensions - from the students of the both groups.

The second and the third graphs (Fig. 2 and 3) describe the mean values to the items of the three dimensions obtained from students of the two groups, paired for each item.

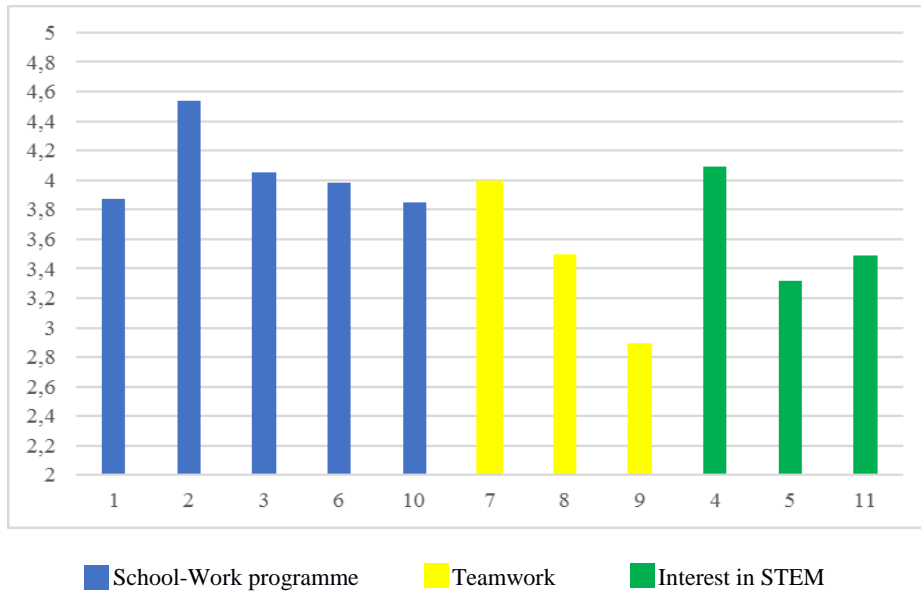


Fig. 1. Mean values from the whole sample (n. = 118 students) to the 11 items of the questionnaires. Mean values for the 3 dimensions (obtained calculating the mean from items of the same dimension) are respectively 4.1, 3.5 and 3.6 – all of them over the threshold of achievement set at 3.0.

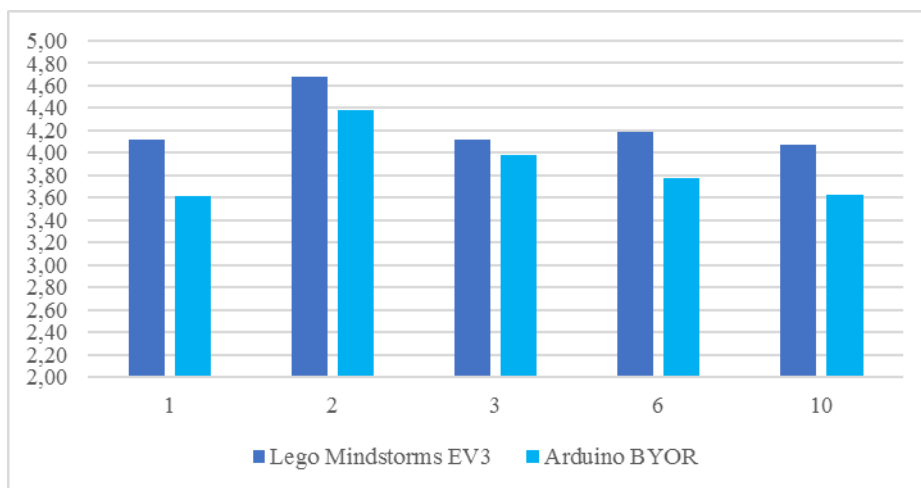


Fig. 2. Mean values of the answers to the items related to appreciation of the School-Work programme given by students of the two samples paired for each item.



Fig. 3. Mean values of the answers to the items related to team work (items n. 7-8-9) and interest in STEM (items n. 4-5-11) given by students of the two samples paired for each item.

5 Conclusion

Data from the questionnaire confirmed that the three objectives of the study have been generally achieved, with mean scores of the dimensions relative to the whole sample over the threshold of 3.0.

For all the 11 items, a constant has been lower scores with Arduino than with Lego. This data - given that the instructor, the topics of the programme and the method were the same in the two classes – could be explained with the higher demand of specific technical skills in the programme with Arduino that could have influenced the level of comprehension of the instructions (item n.1), perceived involvement (item n.10) and interest to repeat experiences with robots in the future (item n.11), those ones with the higher differences between the two classes. This data is also more relevant because the sample of students who worked with Arduino BYOR had initially more technical skills. The availability of an intermediate kit between Lego Mindstorms EV3 and Arduino BYOR in a progressive curriculum in Robotics could be a solution for the difficulties experienced by students.

About the interest in STEM, students reported a relative ease in working with hardware (the construction of robots) with both the two kits, while they met higher difficulties in working with software (in robot programming). This (Coding and Computational Thinking) seems the area that requires more training.

Another evident data is that the programme – with this structure and amount of time – produced in general positive perceptions about class climate, but less ones about collaboration and support in the teams and even less positive evaluations about improvement in peer-relationships; in the class with Arduino, scores related to team work were in general lower than in Lego program. So, we can conclude that this kind of programme is not particularly effective in increasing individual and in-team relationships.

Further considerations will be made from the data of the open-answer questions, which are currently being analysed.

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References

1. OECD (2014), Skills Beyond School: Synthesis Report, OECD Reviews of Vocational Education and Training, OECD Publishing, <http://dx.doi.org/10.1787/9789264214682-en>
2. European Commission/EACEA/Eurydice, 2016. Structural Indicators for Monitoring Education and Training Systems in Europe – 2016. Eurydice Background Report to the Education and Training Monitor 2016. Eurydice Report. Luxembourg: Publications Office of the European Union.
3. <http://www.cedefop.europa.eu/it/news-and-press/news/italy-education-reform>
4. http://www.istruzione.it/alternanza/cosa_alternanza.shtml
5. Dede, C.: Comparing frameworks for 21st century skills. 21st century skills: Rethinking how students learn 20, pp. 51-76. (2010)
6. Eguchi, A.: Educational robotics to promote 21 st century skills and technological understanding among underprivileged undergraduate students. Integrated STEM Education Conference (ISEC), 2015 IEEE. IEEE, (2015).
7. Scaradozzi, D., Screpanti, L., Cesaretti, L., Mazzieri, E., Storti, M., Brandoni, M., Longhi, A.: "Rethink Loreto: we build our smart city!" A STEM education experience for introducing smart city concept with educational robotics, The 9th annual International Conference of Education, Research and Innovation, ICERI2016, Seville, Spain (2016).
8. Scaradozzi D., Sorbi L., Pedale A., Valzano M., Vergine C.: Teaching Robotics at the Primary School: An Innovative Approach, *Procedia - Social and Behavioral Sciences*, pp. 3838-3846, vol. 174, (2015).
9. Caro, D. C., Solorzano, G. P., Avellaneda M. F., Bustos, T. P.: Didactic Material Development for Robotics in Non-Formal Technology Education, 2006 IEEE 3rd Latin American Robotics Symposium, Santiago, pp. 180-186. (2006)
10. Scaradozzi, D.; Pachla, P.; Screpanti, L.; Costa, D.; Berzano, M.; Valzano, M.: Innovative robotic tools for teaching STREM at the early stage of education. Proceedings of the 10th annual International Technology, Education and Development Conference, INTED 2016, Valencia, Spain. (2006)
11. Sowell, E., Waller, L., Ofori-Boadu, A., Bullock, G.: Using technology summer camp to stimulate the interest of female high school students in technology careers, 2016 Portland International Conference on Management of Engineering and Technology (PICMET), Honolulu, HI, pp. 1688-1696. (2016)
12. Lindh, J., Holgersson, T.: Does lego training stimulate pupils' ability to solve logical problems?, *Computers & Education*, Volume 49, Issue 4, Pages 1097-1111. (2007)

13. Goldman, R., Eguchi, A., Sklar, E.: Using educational robotics to engage inner-city students with technology. Proceedings of the 6th international conference on Learning sciences. International Society of the Learning Sciences. (2004)
14. Benitti, F. B. V.: Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education* 58.3, pp. 978-988. (2012)
15. Mitnik, R., Nussbaum, M., Soto, A.: An autonomous educational mobile robot mediator. *Autonomous Robots* 25.4, pp. 367-382. (2008)
16. Oreggia, M., Chiorri, C., Pozzi F., Tacchella, A.: Introducing Computer Engineering Curriculum to Upper Secondary Students: An Evaluation of Experiences Based on Educational Robotics, 2016 IEEE 16th International Conference on Advanced Learning Technologies (ICALT), Austin, TX, pp. 293-294. (2016)
17. Vitale, G., Bonarini, A., Matteucci M., Bascetta, L.: Toward Vocational Robotics: An Experience in Post-Secondary School Education and Job Training Through Robotics, in *IEEE Robotics & Automation Magazine*, vol. 23, no. 4, pp. 73-81. (2016)
18. Papert, S.: *Mindstorms: Children Computers and Powerful Ideas*, New, York:Basic Books, (1993).
19. Papert, S.: *Learn Think to Children*, UCLA (University of California Los Angeles). (1972)
20. Resnick, L.B.: *Education and Learning to Think*. National Academy Press. Washington. (1987)
21. Schank, R.: *Dynamic Memory: A Theory of Learning in Computers and People*. New York: Cambridge University Press, (1982)
22. Gardner, H.: *Intelligenze multiple*, Anabasi, Milano (1994)
23. Likert R.: Technique for the measure of attitudes *Arch. Psycho.*, Vol. 22 N. 140. (1932)