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

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Sommario

Questo articolo presenta un approccio innovativo all'Alternanza Scuola-Lavoro basato sulla Robotica Educativa e sul project-based learning. All'inizio del 2017 (da gennaio ad aprile), il Liceo Volta-Fellini di Riccione ha proposto ai propri studenti un'attività pratica connessa alle STEM, come Alternanza Scuola-Lavoro. Questo corso di Robotica è stato progettato e sviluppato da TALENT srl e dall'Università Politecnica delle Marche con 3 obiettivi principali: accrescere l'interesse verso le discipline STEM, migliorare la capacità degli studenti di lavorare in gruppo, accrescere la consapevolezza degli alunni verso i propri processi cognitivi attraverso la valutazione dell'Alternanza. Sono state coinvolte 6 classi, 3 dell'indirizzo Scientifico e 3 dell'indirizzo Scienze Applicate. Il raggiungimento degli obiettivi è stato determinato raccogliendo dati dagli studenti per mezzo di questionari di autovalutazione; gli studenti hanno espresso il loro livello di accordo alle domande del questionario con una scala Likert a 5 punti: ogni gruppo di domande associato ad uno specifico obiettivo con una media maggiore di 3 permette di considerare quella finalità progettuale raggiunta. Avendo ottenuto come medie per ogni obiettivo 4.1, 3.5 e 3.6 i tre scopi si considerano conseguiti.

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, providing students with the opportunity 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 was evaluated collecting data from students by means of a self-assessment questionnaire; students could express their level of agreement to the questions using a 5-point Likert scale: each group of questions associated to a specific aim with an average value greater than 3 allowed to consider that goal reached. As each objective scored an average value of 4.1, 3.5 and 3.6, authors consider all the three goals accomplished.

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 better connect secondary education 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) and on STEM education 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.

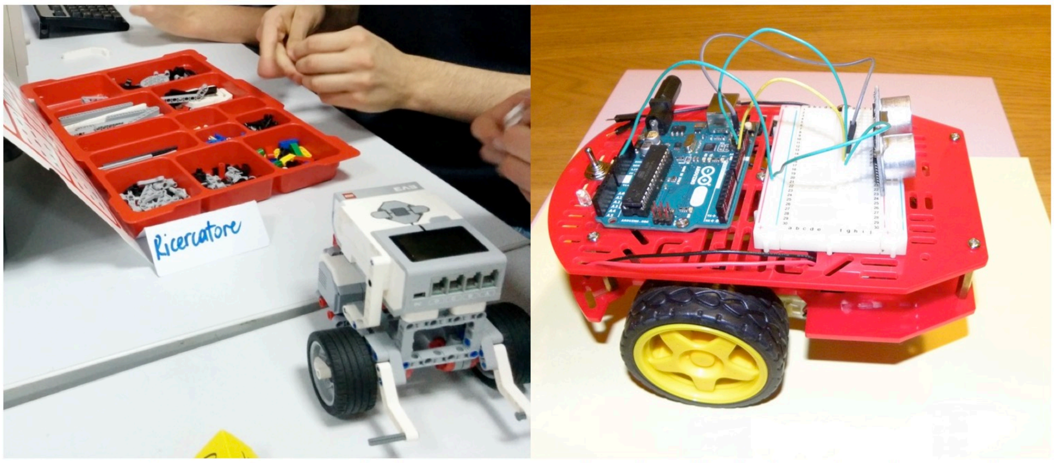

Fig. 1
A picture of Lego Mindstorms EV3 Education kit (left) and a picture of Arduino BYOR kit, developed by Scuola di Robotica (right).

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 Mathematics [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). TALENT srl is an innovative start up with a social vocation, it organizes courses to develop soft skills, critical thinking and human qualities increasing public understanding of technology. Università Politecnica delle Marche has been involved in Educational Robotics since 2010, when a pilot project in the Istituto Comprensivo “Largo Cocconi” in Rome started, with the aim to introduce Robotics as a regular subject at the elementary school.

The expression STEM was created by the National Science Foundation (NSF), and indicates Science, Technology, Engineering, and Mathematics [18]. But this acronym doesn’t only refer to the teaching and learning of these disciplines, indeed STEM education tries to introduce a project-based approach into the classroom, characterized by a student-centered strategy in which pupils learn concepts in an active way, solving problems, designing and experimenting with materials. [19]

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 Section 4 and they will be shown in relation to the three main objectives stated above. 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 [20] 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 educators 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 [21, 22, 23] and on theories oriented to promote different learning styles and "Multiple intelligences" [24].

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 the Robotics laboratories and exploring the possibilities offered by 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), students were presented with a tangible goal to work for: to realize a robot able to follow a black line on a white canvas. Some videos of line-follower robots were presented to demonstrate that assigning this task to a robot is a very common strategy for Robotics insiders, because it solves real problems in several fields (e.g. industrial robotics, service robotics etc.). Then, 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: how 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:

```
If “value read by the sensor” > “mean value”
Then Turn right
Else Turn left
```

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.

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Value = Read Light Sensor
Error = Midpoint – Value
Output = Kp*Error
```

In this case the output of the system was the steering of the robot, that students could set up directly in Lego Mindstorms EV3 software, whereas they had to assign different powers to the motors in Arduino IDE.

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 le 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 [25].

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, Q3, 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:

Q12 - What did you learn in this programme?

Q13 - What was the thing of the programme you liked most?

Q14 - Do you think something didn't go right?

Q15 - Is there something more you would have liked to do in the programme?

4 Results

The following bar graphs (from Fig. 2 to Fig. 4) 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. 2) 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. 3 and 4) describe the mean values to the items of the three dimensions obtained from students of the two groups, paired for each item.

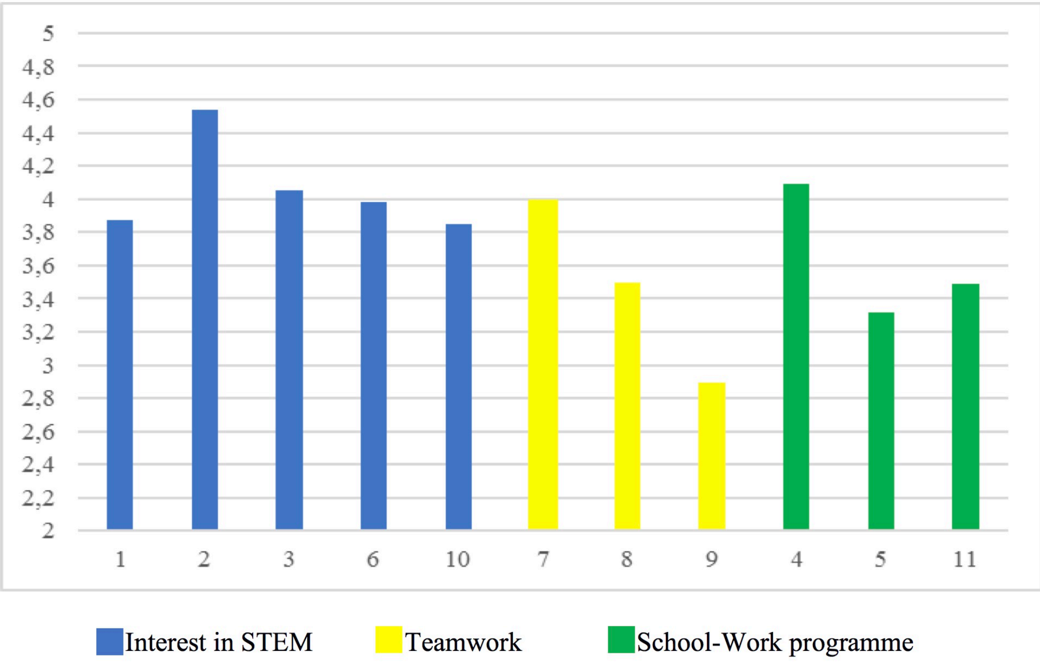

Fig. 2
Mean values from the whole sample (n. = 118 students) to the 11 items of the questionnaires. Mean values for the 3 dimensions (obtained calculating the mean from items of the same dimension) are respectively 4.1, 3.5 and 3.6 – all of them over the threshold of achievement set at 3.0.

Fig. 3.
Mean values of the answers to the items related to interest in STEM given by students of the two samples paired for each item.

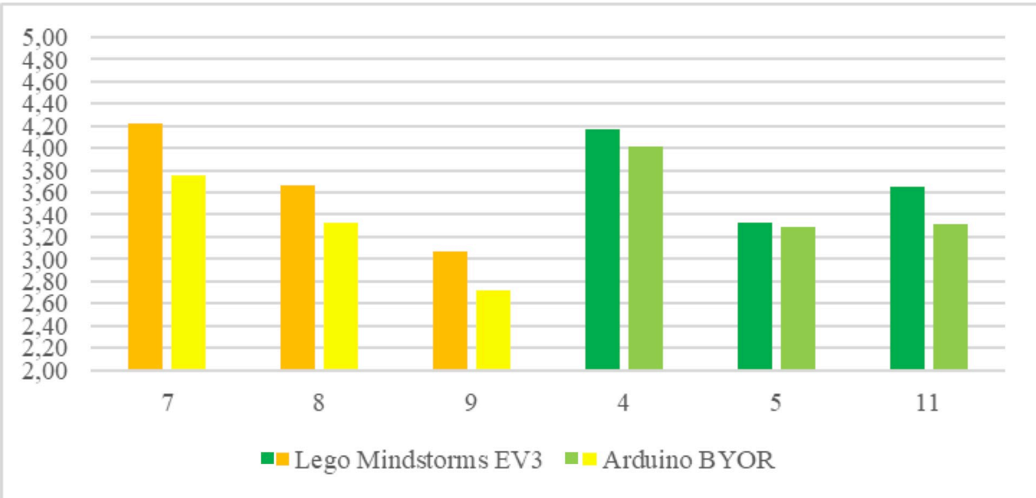

Fig. 4.
Mean values of the answers to the items related to team work (items n. 7-8-9) and appreciation of the School-Work programme (items n. 4-5-11) given by students of the two samples paired for each item.

The following bar graphs (from Fig. 5 to Fig. 12) contain the categories in which we can categorize students' answers to open-ended questions. The 4 items were designed to obtain more information about the achievement of the objectives, and students' opinion about the project.

Fig. 5 shows the answers to the question: "What did you learn in this programme?" for the Lego group. Students' answers are summarised in 8 categories: Programming, Robotics, Teamwork, Flow Diagram Design, Robot Construction, Math, Problem Solving, No answer.

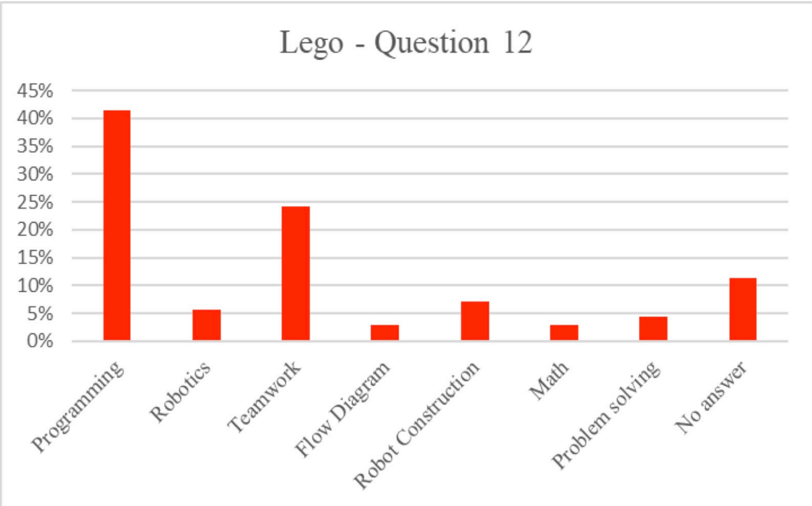

Fig. 5.
Students, answers (Lego group) to the question "What did you learn in this programme?".

Fig. 6 shows the answers to the question: "What did you learn in this programme?" for the Arduino group. Students' answers are summarised in 8 categories: Programming, Robotics, Teamwork, Robot Construction, Hardware, Apply Theory, Few (we have problems), No answer.

Fig. 6.
Students' answers (Arduino group) to the question "What did you learn in this programme?".

Fig. 7 shows the answers to the question: "What was the thing of the programme you liked most?" for the Lego group. Students' answers are summarised in 7 categories: Challenges, Programming, Teamwork, Robot Construction, Achieve Objectives, Educator, No answer.

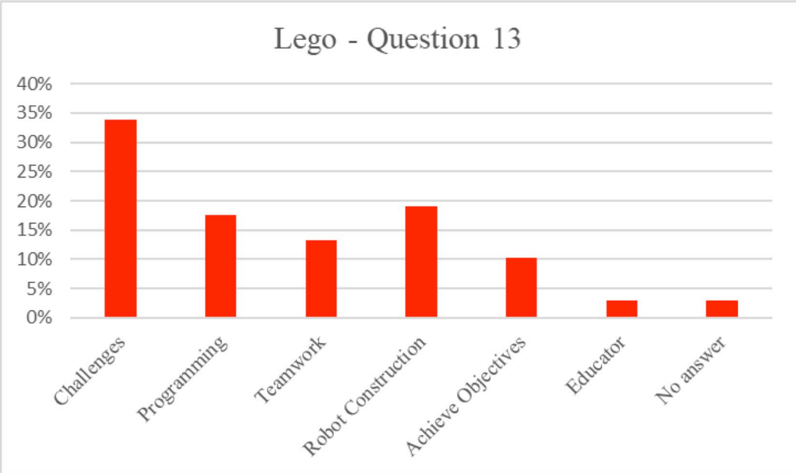

Fig. 7.
Students' answers (Lego group) to the question "What was the thing of the programme you liked most?"

Fig. 8 shows the answers to the question: "What was the thing of the programme you liked most?" for the Arduino group. Students' answers are summarised in 7 categories: Challenges, Programming, Teamwork, Robot Construction, Circuits Making, Educator, No answer.

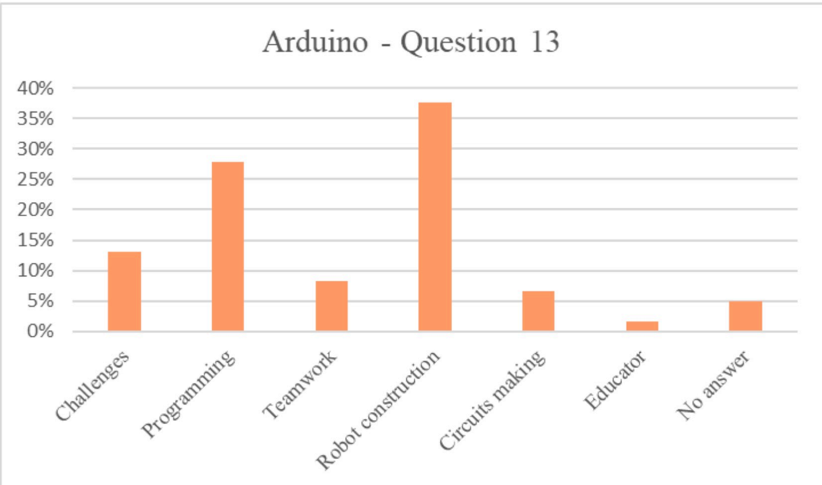

Fig. 8.
Students' answers (Arduino group) to the question "What was the thing of the programme you liked most?".

Fig. 9 shows the answers to the question: "Do you think something didn't go right?" for the Lego group. Students' answers are summarised in 6 categories: Everything Well, Teamwork, Theory of Programming, Not interested in STEM, Timetable, No answer.

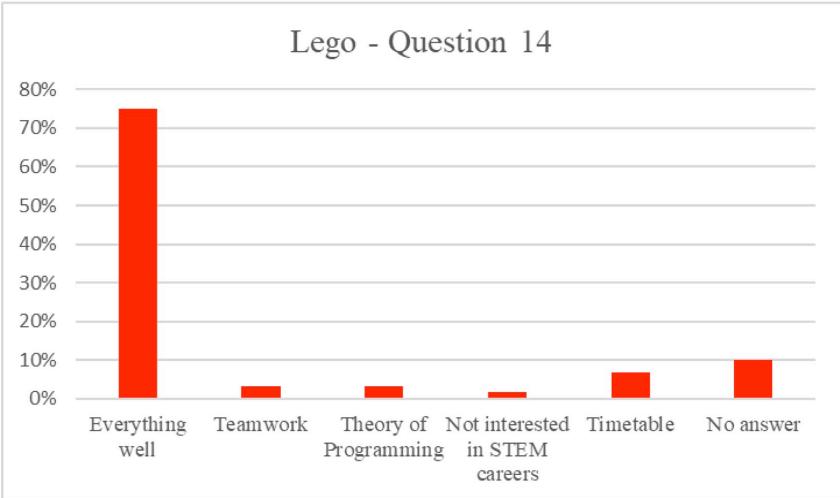

Fig. 9.
Students' answers (Lego group) to the question "Do you think something didn't go right?".

Fig. 10 shows the answers to the question: "Do you think something didn't go right?" for the Arduino group. Students' answers are summarised in 7 categories: Everything Well, Teamwork, Programming, Hardware, No theory knowledge, Few Time, No answer.

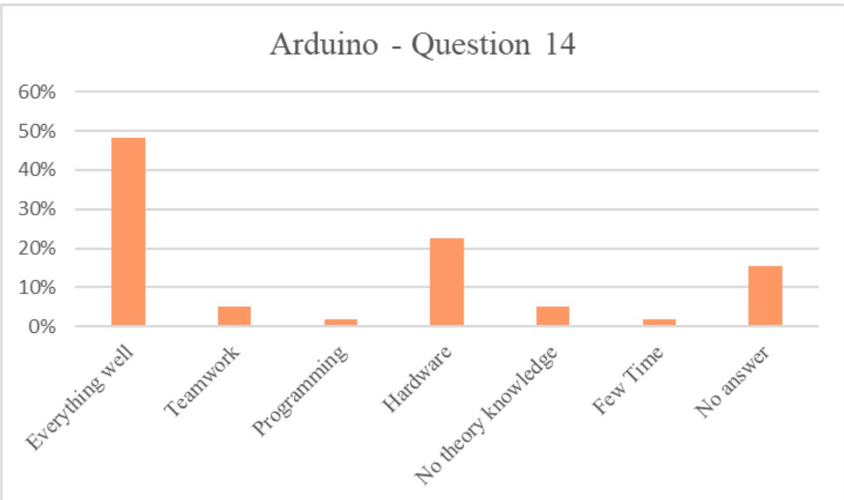

Fig. 10.
Students' answers (Arduino group) to the question "Do you think something didn't go right?".

Fig. 11 shows the answers to the question: “Is there something more you would have liked to do in the programme?” for the Lego group. Students’ answers are summarised in 5 categories: Programming, Nothing, More Challenges, Other robots, No answer.

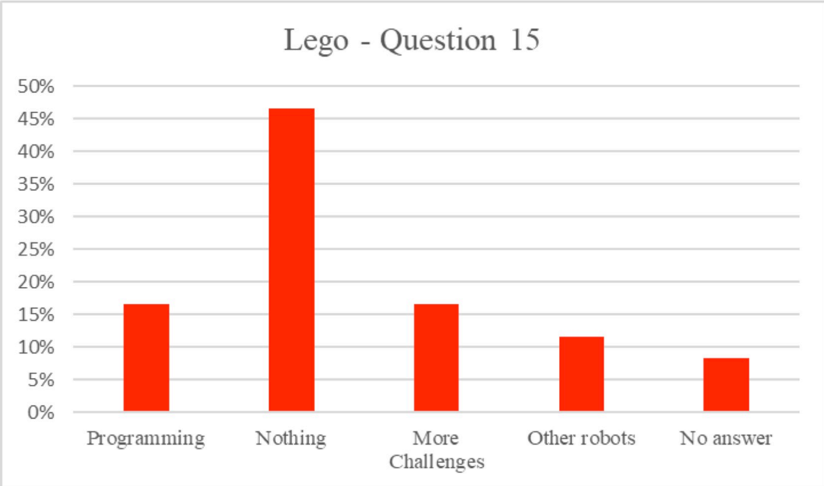

Fig. 11.
Students’ answers (Lego group) to the question “Is there something more you would have liked to do in the programme?”.

Fig. 11 shows the answers to the question: “Is there something more you would have liked to do in the programme?” for the Arduino group. Students’ answers are summarised in 5 categories: Programming, Nothing, More Challenges, Other robots, No answer.

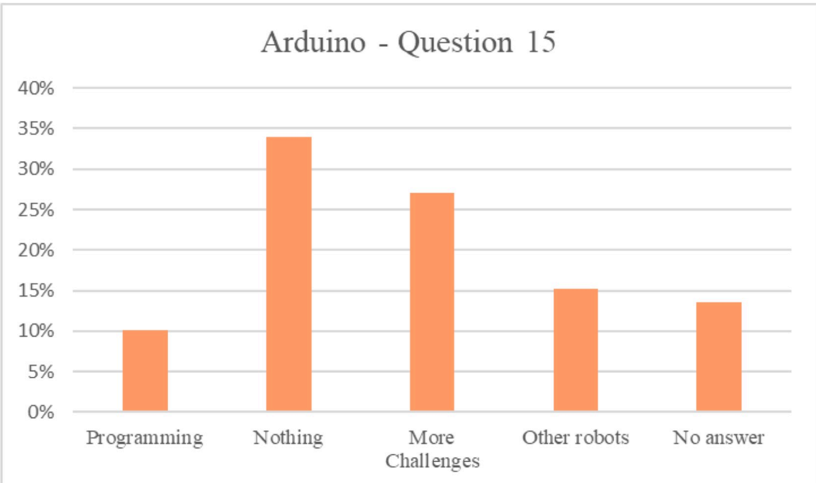

Fig. 12.
Students’ answers (Arduino group) to the question “Is there something more you would have liked to do in the programme?”.

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.

It is to be noted that throughout all the first eleven items of the questionnaire students that have worked with the Arduino-based kit assigned lower scores with respect to their colleagues that have worked with the Lego kit. Given that the two groups shared the same instructor, dealt with the same topics and the same method was used during the activities, students assigning lower scores in Q1 through Q11 could be explained with the higher demand of specific technical skills while dealing with Arduino. This seems to have influenced the general perception of the activities and in particular 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), as these items reported higher differences between the two classes. This data could be 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 Mindsotorms 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 kits, while they had greater difficulties in working with software (in robot programming). This (Coding and Computational Thinking) seems to be the area that requires more training.

Another evident data is that the programme – with this structure and amount of time – generally produced positive perceptions about climate in the class, 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 the Lego program. So, we can conclude that this kind of programme is not particularly effective in increasing individual and in-team relationships.

Analysing the answers to open-ended questions, it's possible to extrapolate different conclusions, considering each item:

Q12 – Both groups stated that they learned "Programming" (41% Lego, 37% Arduino), but only some students in the Lego group (25%) answered that they had learned "Teamwork" during the activities. Maybe Arduino BYOR is a more cognitively challenging kit, demanding most of the intellectual resources of students (e.g. in terms of selective attention and working memory), that are concentrated on the technological devices rather than on the teamwork processes. More than 30% of students in the Arduino group had the perception of learning about something related to hardware (circuit making or robot construction), whereas only 7% of pupils in the Lego group had this feeling; this fact didn't surprise us, because working with Lego Mindstorms EV3, it's not possible to see the hardware behind the robot, and it's not possible to create any circuit to make the robot ready for the challenges.

Q13- The favourite aspect (37%) that students belonging to the Lego group found in the programme was having the possibility to challenge other groups programming the robots. Only 13% of students from the Arduino group wrote the same concept, maybe because technical problems and difficulties impeded them to live the challenge situation positively. Probably there was a lack of perceived self-efficacy during the activities, that led to a lack of self-confidence in facing the challenges, and experiencing them without anxiety.

Another fact that confirmed this analysis was the educator's report, where it's possible to read that often challenges for the Arduino groups were slowed down because of technical problems (software and hardware) that students were not able to solve.

We can conclude that where the activity was full of challenges (without a lot of technical difficulties), challenge was experienced as a strength; where the activity wasn't characterized by a lot of challenges, the most frequent answers were about hardware making or robot programming.

Q14- This question presents a large difference between the "Everything is good" answer: 75% of students in the Lego group stated that there weren't any problems during the activities, against only 48% of students in the Arduino group; but this group was characterized by 21% of the sample that affirmed to have hardware problems. The educator reported that these problems were related not only to the difficulties in circuit making or robot construction, but also to the management of the robotic kits (8 kits that 60 students had to share). With a large number of kits we probably wouldn't have had this percentage of students dissatisfied with the hardware.

Q15- 47% of students belonging to the Lego group affirmed that they were satisfied with the course and didn't want to go any further, doing something more advanced. Probably the non-technical orientation of the school (scientific course) influenced this choice.

27% of students in the Arduino group wanted to go ahead participating in further challenges; this data reinforces our hypothesis presented for the item Q13: students in the Arduino group wanted to make competition, but technical problems created obstacles to work with a challenge-based approach.

Another important data we want to present concerns the percentage of students that were able to program the robot for the last activity (Obstacle avoidance during the line following); although all the groups demonstrated involvement to achieve this objective, we could measure this different result:

- 90% of the students in the Lego group were able to program the robot obtaining the desired behavior;
- 20% of the students in the Arduino group were able to program the robot obtaining the desired behavior.

We can conclude that more lectures would probably be necessary for the group working with Arduino, or maybe we should have proposed a more structured introductive phase, to reinforce the students' confidence with Arduino BYOR.

This experimental study proves the effectiveness of challenge-based approach (when there are the proper prerequisites), in particular related to STEM disciplines and to Robotics. We think that it's possible to obtain a deep understanding of theoretical concepts and a real involvement of students adopting this kind of strategy, characterized by brief frontal moments (it's necessary to give students the tools to design correctly), teamwork to solve problems and prepare challenges.

6 Further steps

Next steps we want to implement for further projects regard:

1. A measurement of the perceived self-efficiency; it's necessary to control this variable, as stated in section 5 (in the analysis of item Q13);
2. The research of a strategy to make the activities with Arduino BYOR comparable (in terms of efficacy) to the activities with Lego Mindstorms EV3. Maybe another way could be the choice of another kit (or the design of it) with the same specs: the possibility to create circuits and to program the robot in textual languages.
3. The design of objective assessment tools, to evaluate technical skills acquired during the alternating School-Work programme (programming, circuit making, etc.); we want to take into consideration not only the achievement of a final specific goal, but also the development of the project and the learning level reached by the students (all the skills put in place by the pupils involved).

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