AN EDUCATIONAL ROBOTICS ACTIVITY TO PROMOTE GENDER EQUALITY IN STEM EDUCATION

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Abstract

In the future boys and girls will be employed in, and maybe create, new jobs connected with technology. We present a project whose aim was to raise interest in STEM education in K12 students and, in particular, to address the lack of participation of female students in STEM careers. For this reason, in September 2017, 20 students (12 girls and 8 boys) took part in a two-weeks robotic camp to learn robotics and its application on agriculture. An evaluation of attitudes and performances was accomplished by delivering a questionnaire and by recording the results from day-to-day challenges.

Context of the Study

Women around the world have been fighting for their own basic rights for centuries. All the basic human rights had to be conquered through the years, and now, even if something has already been achieved, the effects of gender inequality still persist. They persist for example in stereotypical gender perceptions that affect people's reasoning in every aspect of everyday life, across different generations and cultures. The weight of gender discrimination assigns strict roles to both men and women producing harmful effects, because it represents a limit for our mind and therefore for society at large.

A study from the European Institute for Gender Equality (EIGE) reports that the term *gender equality* itself is not well understood, as it is mostly regarded as a women's issue (EIGE, 2012). On the contrary, the European Commission (EC) defines gender equality as "the result of the absence of discrimination on the basis of a person's sex in opportunities and the allocation of resources or benefits or in access to services" (p. 16). Even though all ages should be targeted to face inequalities, Biemmi and Satta (2017) state that stereotypes and prejudices, including those regarding gender, are the result of social categorization that begins in the first years of life (e.g., pink is the colour for girls and blue for boys), and it continues thereafter becoming increasingly invasive. Even if school could promote projects on emotional education and respect for differences, the dominant school model remains the traditional one where these processes are rarely present.

Another aspect of gender equalities is explored by Han (2016), who studied the association between features of national educational system and gender gap in STEM related occupational expectancy across 49 countries, including Italy, examining data from PISA 2006. Gender gap in STEM education, career and wages, in fact, can be influenced both by individual factors and by macro-level factors, such as stratification and standardization of educational systems. Stratification of education systems seems to be associated with a larger gender gap in STEM occupational expectancy. Moreover, top-performers seem to show a stronger relation between the availability of several school types at the secondary level of education and expectations of students for their future career. An Italian national source for statistical data (Servizio Statistico MIUR – 2016) stated that only a few female students pursue a STEM career: only 16.3% of students choosing vocational education on technical fields are girls.

Moreover, in the academic year 2014/15 the share of female students enrolling for their first year in a bachelor course in the field of Humanities was 75%, whereas only 31% of girls chose a technical course like Engineering. The reasons why girls do not pursue a technical career could be related to socio-cultural motivations as well as educational, but the worst thing is that this is echoed in the difficulty of accessing those careers that are strongly related to science and technology. Unfortunately, these careers are the most promising, in terms of future employability and economic reward, and it is therefore impairing for women not to benefit from this opportunity. The Italian Department for Gender Equality (Dipartimento per le Pari Opportunità della Presidenza del Consiglio dei Ministri – DPO) and the Italian Ministry of Education (Ministero dell'Istruzione, dell'Università e della Ricerca - MIUR) chose to take action against this situation and launched a call for proposals. This call intended to fight stereotypes describing girls as unfit for studying STEM subjects by involving primary and lower secondary schools in a summer activity on math, science, technology, computer science and coding.

Robotics as Mean to Foster STEM Education

To involve and motivate girls to think about a future career in STEM related fields, authors relied on some personal experiences (Cesaretti et al., 2017; Scaradozzi, Sorbi, Pedale, Valzano, & Vergine, 2015; Scaradozzi et al., 2016a; Scaradozzi et al., 2016b; Scaradozzi, Screpanti, Cesaretti, Storti, & Mazzieri, 2018) and some literature findings reporting positive results in fostering STEM by means of Educational Robotics (ER). First of all, Sanders (2009) states that Robotics is the true integrated approach to STEM education, meaning that it can put STEM fields together fostering the re-elaborations of notions and an active learning. Moreover, ER education can also empower future citizens of the digital world and the nowadays boys and girls in the field of Cybersecurity (Kasemsap, 2017), enabling them to protect themselves from the potential danger of a connected life. Benitti (2012) showed that ER holds a great potential, even if it hasn't reached its full expression in terms of research outcomes, because research in this field lacks large samples for quantitative investigations. A further investigation by Mubin, Stevens, Shahid, Al Mahmud, and Dong (2013) states that research is still needed to make robots and curricula fit for students. Later on, we can find examples of ER curricula into schools. For example, the work of Veselovská and Mayerová (2017) presents qualitative evaluation of activities from an ER curriculum developed for lower secondary students. Scaradozzi et al. (2015) and Scaradozzi et al. (2016a) present features and some results from an experimental curriculum on robotics as a curricular subject in an Italian primary school.

Robotics and Its Impact on Gender Equality

Master, Cheryan, Moscatelli and Meltzoff (2017) studied 96 children holding strong stereotypes that boys were better than girls at robotics and programming. Girls reported lower interest and self-efficacy in these domains than boys. Boys and girls participating in the treatment group (they were both involved in robotics and programming activities) reported a significant change in interest and self-efficacy. Especially, girls of the treatment group reported higher technology interest and self-efficacy if compared with girls belonging to the control group, that did not experience the activities. Moreover, they did not show a significant gender gap relative to boys' interest and self-efficacy. Reich-Stiebert and Eyssel (2017) studied university students, evaluating the impact of gender on robotic activities. They argued that if teachers' gender influences students' learning outcomes and motivation, robots can produce a similar bias. They found that robots' gender had no influence over the sample and, unexpectedly, the gender-stereotypical tasks increased the willingness of participants to put all their efforts in overcoming the stereotypes. Also, at the European level, robotics is considered an effective means to reduce the gender gap. We can mention just two (out of more) EU funded project on the topic: "TWIST" (http://www.the-twist-project.eu/en/) and "Roberta goes EU" (https://cordis.europa.eu/result/rcn/46888_en.html). To reach a robust, sustainable European economy which can compete with new emerging markets, the female capacity must be developed and deployed effectively. To this end, TWIST (Toward Women in Science and Technology) created genderless activities in science centres and museums. "Roberta goes EU" addressed the lack of female engineers by carrying out activities of robotics in a variety of environments reporting positive results.

Methods

The following subsections provide an account of the activities of the project, which took place in Ancona (Italy) at the school I.C. Novelli Natalucci in September 2017. The school, the university Università Politecnica delle Marche and the start-up TALENT srl. co-designed a two-weeks activity on robotics and its application to agriculture. The university prepared some of the materials and tools to make it possible for students to build and program the automated vegetable garden. The university also provided support in the design of activities and analysis of results. TALENT srl. carried out the activities in the classroom involving the students in meaningful activities.
In the following subsections authors provide further details on the activities.

Underlying Pedagogical Approach

The pedagogical theory that helped designing and carrying out activities was constructionism, which suggests that building knowledge is the natural consequence of an experience of creation and experimentation. Students are encouraged to directly observe their own actions and analyse the consequent effects. They are called to share ideas in a highly motivating context. From this point of view, technology and innovative learning environment let students learn with their peculiar style of learning. Relying upon Gardner's theory of multiple intelligences, students are encouraged to acknowledge their own skills and abilities. This can help them to think about their future, both in terms of studies and career. A learner-centred approach was employed, problem-based learning (PBL): after a brief explanation of the fundamental aspects of robotics, students faced challenges focused on the collaborative research of effective solutions, thus fostering also project-based learning and peer tutoring. All the activities were designed on the TMI model (Think, Make, Improve), as suggested by Martinez and Stager (2013): first, students try to figure out what a solution to the problem can look like (Think); second, students try to realise the solution by building and programming the robot (Make); third, students watch closely their artefacts and try debug or improve them (Improve).

Tools and Materials

The following list of materials illustrate what a single group of students used during the activities:

- 1 kit Lego Mindstorms EV3 Education
- software Lego Mindstorms EV3 Home Edition
- 1 kit Lego Pneumatic Add-on Set
- 1 kit Lego Renewable Energies
- 2 sensors Mindstorms Temperature Sensor
- 1 sensor SparkFun Soil Moisture Sensor
- 1 Arduino EV3 Adapter
- 1 Arduino UNO board
- Spare materials (plastic bottles, tape, etc.)

Contents of the activities

The project lasted two weeks: 5 days a week and 4 hours of activities planned each day. Week 1 was focused on providing all students with the basic notions on robotics. Week 2 was focused on designing, building, programming and testing a robotic structure whose aim was to simplify the daily work of a hypothetic farmer in a vegetable garden. Week 1 offered a more structured kind of activity, while Week 2 purposefully left students free to explore solutions, thus fostering responsibility, autonomy and self-confidence. The schedule of activities for Week 1 is:

- Day 1: Designing a robot: the roles. (Defining team and roles; How to build a simple program; How to build a simple robot; Challenge 1).

- Day 2: Man-Machine-Robot: what's the difference? (What is a machine? What is a robot? Differences and similarities between men, machines and robots; Challenge 2; Challenge 3).
- Day 3: The artificial brain of a robot (Sequencing, Selection, Iteration: three ways to code; Challenge 4; Challenge 5).
- Day 4: Debugging (How to find software errors; Challenge 6; Challenge 7).
- Day 5: Final challenge (Complex instructions that build on skills acquired during the previous activities; Challenge 8).

The schedule of activities for Week 2 is:

- Day 1: The vegetable garden (Designing the vegetable garden: what sensor and actuators should we use?).
- Day 2: Robotic artefacts to build the automatic vegetable garden (Building sensors and actuators).
- Day 3: Robotic artefacts to build the automatic vegetable garden (Testing sensors and actuators).
- Day 4: Sharing the artefact: implementation. (How to present the whole automatic vegetable garden: building and programming a story).
- Day 5: Final Exhibition. (Teachers, parents and locals are invited to the great exhibition of the automatic vegetable garden).

Participants
The call for proposal required 20 students; 60% of them had to be female. The age range of participants was from 11 years old to 13 years old. Not all participants came from the same school or class. A personal choice of educators was to divide participants into six groups. The aims of this choice were to provide students with the possibility to expand their personal abilities by combining them with those of their teammates and to learn to manage themselves and the others to accomplish tasks within the time at their disposal. Table 1 (p. 326) reports the distribution of students' gender between groups in the first two columns.

Challenges
Challenges were designed to stimulate participants to use the knowledge they acquired, reworking it to build and program a robot. The educator acted as a facilitator and as a judge in the challenges. Tasks in each challenge were:

- Challenge 1: The mobile robot had to cover a distance (1 metre).
- Challenge 2: The mobile robot had to move across an established path (without using sensors).
- Challenge 3: The mobile robot had to move along a square path (without sensors).
- Challenge 4: The mobile robot had to use a gyroscope to rotate.
- Challenge 5: The mobile robot had to use a gyroscope to move across a square path.

- Challenge 6: The mobile robot had to use an ultrasonic sensor to reach a fixed distance from an obstacle (25 cm).
- Challenge 7: Students had to find the bug in the project of a mobile robot using an ultrasonic sensor to perform a task.
- Challenge 8: Final path for a mobile to follow.

Questionnaire
At the end of the project, participants answered a questionnaire aiming to assess their attitude towards the activities. It was divided into 14 Likert-type items (Q1-14) and 4 open-ended questions (Q15-18). Items are:

- Q1 - I understood the instructions and the explanations that the trainer gave me.
- Q2 - The trainer was helpful and careful to my needs and questions.
- Q3 – I found engaging the method that the trainer employed.
- Q4 - It was easy to build in team all the robots and the automatic vegetable garden with my group.
- Q5 - It was easy to use the software and the pc.
- Q6 – I attended gladly to the activities.
- Q7 - The classroom's environment was peaceful.
- Q8 - My team got on well together and we helped each other.
- Q9 – My relationship with one (or more) classmate(s) improved.
- Q10 - I think I understood the fundamentals of building a robot and a technological vegetable garden.
- Q11 - It was fun to discover how to build a robot and a technological vegetable garden.
- Q12 - I think I understood the fundamentals of programming a robot and a technological vegetable garden.
- Q13 - It was fun to discover how to program a robot and a technological vegetable garden.
- Q15 - I also learnt …
- Q14 - I'd like to be involved in other activities of Robotics.
- Q16 - What is the thing you liked the most in this laboratory?
- Q17 - In your opinion, is there anything that went wrong?
- Q18 - Is there anything you would have liked to do in the laboratory?
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The rating scale for Q1-Q14 was: 1 (No, at all), 2 (A little), 3 (Enough), 4 (Very much), and 5 (Yes, definitely). Students answered to Q15-18 writing free text. To evaluate results authors explored groups of questions targeting:

- *Educator*: relationship between students and educators (Q1-3).
- *Building:* building robots and the automatic vegetables garden (Q4, Q10-11).
- *Programming:* programming robots and the automatic vegetables garden (Q5, Q12-13).
- *Teamwork*: teamwork attitude (Q6-9).

Q14 is a global index, because if students had been positively involved, we could presume that they might be interested in carrying out some other similar activities. This is an important question because the final objective of the whole project is to raise interest toward STEM education and careers in young girls. To analyse open-ended questions (Q15-18), authors regrouped similar answers and labelled them into categories, following the main actions recalled by words and phrases used by students in the free text:

- Using/programming; understanding; inventing; cooperating (Q15).
- Cooperating; building; programming; challenge; teachers (Q16).
- No; Yes, cooperating; Yes, decorating; Yes (Q17).
- No; Yes, building; Yes, decorating; Yes, cooperating; Yes, more (Q18).

Results

The following subsections provide information about results from the project. Challenges, questionnaires and artefacts built within the project are shown and will be discussed in the final section of this paper.

Challenges

Table 1 shows the results from each challenge. Groups are reported in rows. The first two columns show the Female (F) and Male (M) representation within groups. Columns show results from challenges. The last column ("Rank") shows the final rank of each group. Numbers from 1 to 6 represent the rank the group obtained from the challenges. Actually, there were several ex-equo, thus resulting in a range of ranks from 1 to 4.

Table 1

Results From Each Challenge

	F	*M*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*Rank*
Yellow	3	0	1	2	2	1	1	2	3	4	2
Pink	0	3	1	1	3	1	3	3	1	1	1
Green	0	3	2	3	1	2	3	4	3	2	3
Blue	3	0	4	4	2	2	2	1	3	2	3
White	4	0	3	3	3	3	2	1	1	4	3
Beige	2	2	4	4	3	2	2	2	2	3	4

Questionnaires.

Mean results from areas for questions from Q1 to Q14 are shown in Figure 1. Results from Q15, Q16, Q17 and Q18 are reported in Figure 2.

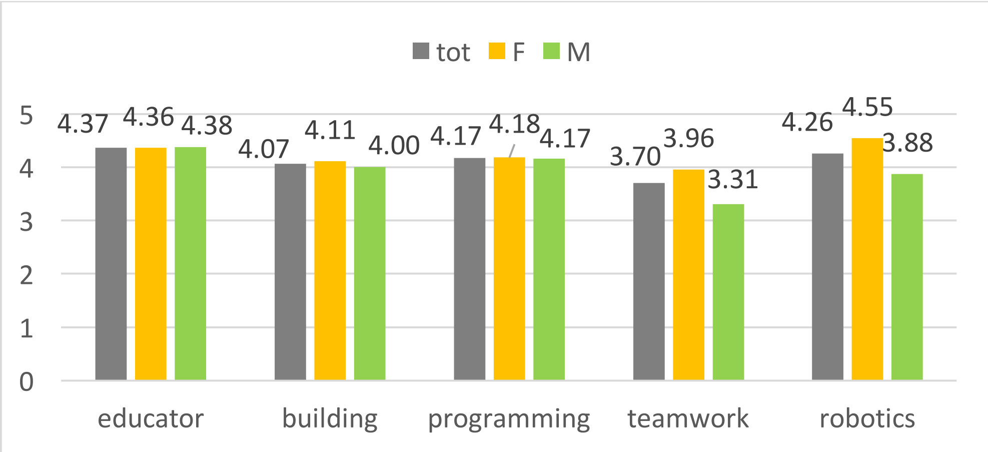

Figure 1. Mean values of answers to open questions per area. Green bars refer to male students, yellow to female students and grey to all students.

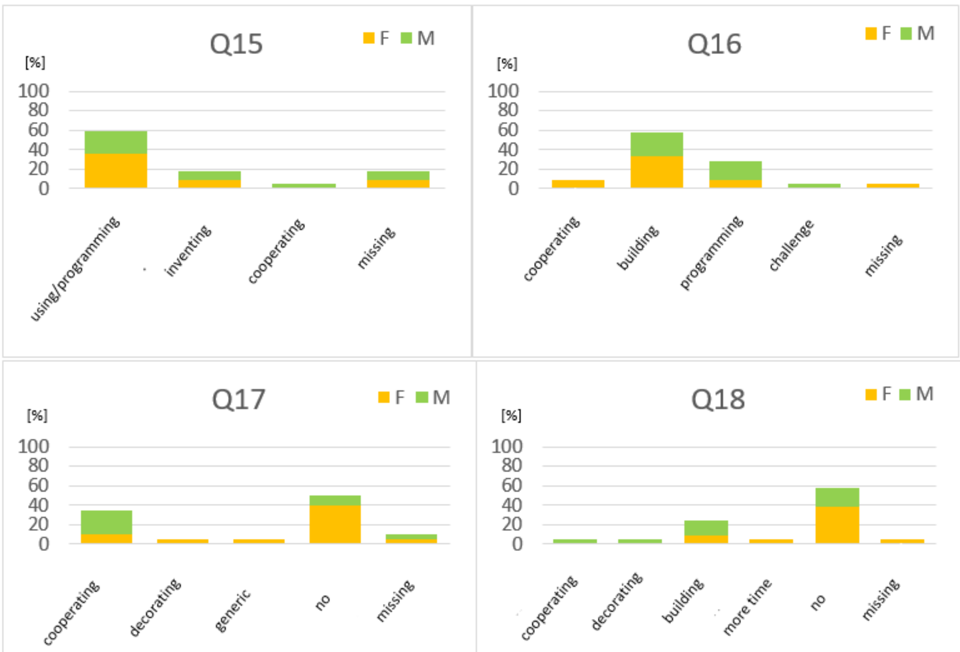

Figure 2. These four graphs show how many students answered and how they answered to Q115, Q16, Q17 and Q18.

Artefacts.

Figure 3 shows the final artefact of the project. Three small plants were used as case studies for implementation. Rosemary (on the right of the picture) was monitored by a humidity sensor, which acquired data from the soil, and a pump, that forces water through the hose. When the humidity sensor reports a value below the threshold, the water is pumped through the hose, otherwise the pump is still. Sage (on the left of the picture) was monitored through a light sensor and an LED: if the environmental light falls below a threshold an LED is lighted up, otherwise it is turned off. Basil (the plant in the middle) is monitored by a temperature sensor, which measures the soil's temperature and reads the value on the EV3 brick display. If the value is acceptable the light on the EV3 brick is green, otherwise the light turns red. There is also a mobile robot (on the right), equipped with an ultrasonic sensor that continuously patrols the table's perimeter, without falling down, to shoo away flies.

Figure 3. This picture shows the final artefact of the activity.

Discussions and Conclusions

Questionnaires (Figures 1 and 2) showed a good liking for activities in each area. The most appreciated area seems to be the *educator* area, while *teamwork,* even reporting overall positive results (mean rating=3.70), has lower ratings if compared with other areas. Looking closely, there seem to be some differences between male and female students: liking for teamwork is higher for girls than for boys. Mean values for Q7, Q8 and Q9 in all the 20 students are respectively 3.05, 3.55 and 3.7, while Q6 is 4.6. This seems to highlight that on average activities were perceived as likeable, but boys (mean values for Q7, Q8, Q9 respectively equals to 3, 3, 3.13) were less inclined than girls (mean values for Q7, Q8, Q9 respectively equals to 3.08, 3.92, 4.08) to work in a team. This result is in line with what educators noticed during the project and with results from Q17 in Figure 2. Looking at the final scores (see Table 1), best ranks are achieved by groups made up of girls. Worst position is achieved by the group made up of 2 boys and 2 girls. The best growth trend is reported by the group "Blue," which stunned the educator with tenacity and behaviour. *Building* and *programming* seem to be appealing to both boys and girls, but looking at Figure 2 it seems that students would have liked to have more building in their activities. This may be an interesting hint for future activities as it could be introduced a different schedule of activities to balance the time spent in building and programming. The overall experience was positive in many ways. Girls involved reported not only good results in terms of achievement, but they also stated to be interested in having more experiences in the field of technology (see *robotics* in Figure 1), which was the main goal of the project, but more importantly this is an objective for society at large.

References

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education*, *58*(3), 978-988. doi: 10.1016/j.compedu.2011.10.006

Biemmi I., & Satta, C. (2017). Childhood, education and gender. The construction of gender culture in classroom, after-school and family settings. *About Gender International journal of Gender Studies*, *6*(12), 1-20. doi: 10.15167/2279-5057/AG2017.6.12.491

Cesaretti, L., Storti, M., Mazzieri, E., Screpanti, L., Paesani, A., Principi, P., & Scaradozzi, D. (2017, November). An innovative approach to school-work turnover programme with educational robotics. *Mondo Digitale*, *72.* Retrieved from http://mondodigitale.aicanet.net/2017-5/best_papers_didamatica_2017/MD72_03_paper_64.pdf

European Institute for Gender Equality (EIGE). (2012). *The involvement of men in gender equality initiatives in the European Union*. Luxembourg: Publications Office of the European Union. doi:10.2839/48546

Han, S. W. (2016). National education systems and gender gaps in STEM occupational expectations. *International Journal of Educational Development*, *49*(C), 175-187. doi: 10.1016/j.ijedudev.2016.03.004

Kasemsap, K. (2017). Robotics: Theory and applications. In M. Moore (Ed.), *Cybersecurity breaches and issues surrounding online threat protection*, Hershey PA: IGI Global (pp. 311-345). doi: 10.4018/978-1-5225-1941-6.ch013

Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

Master, A., Cheryan, S., Moscatelli, A., & Meltzoff, A. N. (2017). Programming experience promotes higher STEM motivation among first-grade girls. *Journal of Experimental Child Psychology*, *160*, 92-106. doi: 10.1016/j.jecp.2017.03.013

Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning*, *1*(209-0015), 13. doi: 10.2316/Journal.209.2013.1.209-0015

Reich-Stiebert, N., & Eyssel, F. (2017, March). (Ir) relevance of Gender? On the influence of gender stereotypes on learning with a robot. In Proceedings of *the 2017 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 166-176), Vienna, Austria. New York, NY: ACM. doi: 10.1145/2909824.3020242

Sanders, M. (2009). STEM, STEM Education, STEM mania. *Technology Teacher, 68*(4), 20-26. Retrieved from: http://esdstem.pbworks.com/f/TTT+STEM+Article_1.pdf

Scaradozzi, D., Sorbi, L., Pedale, A., Valzano, M., & Vergine, C. (2015). Teaching robotics at the primary school: an innovative approach. *Procedia-Social and Behavioral Sciences*, *174,* 3838-3846. doi: 10.1016/j.sbspro.2015.01.1122

Scaradozzi, D., Pachla, P., Screpanti, L., Costa, D., Berzano, M., & Valzano, M. (2016a). Innovative robotic tools for teaching STREM at the early stage of education. *Proceedings 10th International Technology,* *Education and Development Conference (INTED),* Valencia, Spain. doi: http://dx.doi.org/10.21125/inted.2016.2292

Scaradozzi, D., Screpanti, L., Cesaretti, L., Mazzieri, E., Storti, M., Brandoni, M., & Longhi, A. (2016b). "Rethink Loreto: We build our smart city!" A stem education experience for introducing smart city concept with the educational robotics. *Proceedings 9th annual International Conference of Education, Research and Innovation (ICERI 2016)*, Seville, Spain. doi: 10.21125/iceri.2016.1172

Scaradozzi, D., Screpanti, L., Cesaretti, L., Storti, M., & Mazzieri, E. (2018). Implementation and assessment methodologies of teachers' training courses for STEM activities. *Technology, Knowledge and Learning*, 1-21. doi: 10.1007/s10758-018-9356-1

Veselovská M., & Mayerová K. (2017). Programming constructs in curriculum for educational robotics at lower secondary school. In D. Alimisis, M. Moro, & E. Menegatti E. (Eds.), *Educational robotics in the makers era.* Conference Proceedings Edurobotics 2016 (pp. 242-245). doi: 10.1007/978-3-319-55553-9_22

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