

# Young Girls and Careers in science: May a course on robotics change girls' aspirations about their future? The ROBOESTATE Project\*

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## Abstract

This paper presents a study intended to investigate the effects on children's career choices of the ROBOESTATE project, a summer camp aimed at introducing boys, but especially girls, to STEMs through educational robotics activities. Our reflection focused mainly on two research questions: (RQ1) May a course designed like ROBOESTATE encourage students, in particular female students, to pursue a STEM career? (RQ2) Did parents' opinions about STEM careers for their daughters/sons change after ROBOESTATE, especially for those who saw STEM careers as not practicable and/or not desirable? We conducted a quantitative and a qualitative analysis. Although the limited number of data collected during ROBOESTATE does not allow us to give a statistical significance to our results, we can say that ROBOESTATE-like courses increase boys', and especially girls', interest in STEM careers.

**Keywords:** Educational Robotics and Children; Science Careers and Girls; Parents and STEM Careers for Girls

\* Appendices quoted in this article can be found on QWERTY website: <http://www.ckbg.org/qwerty/index.php/qwerty/issue/view/41>.

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## 1. Introduction

In 2017, the ROBOESTATE project proposed a summer camp aimed at introducing boys but especially girls aged 8 to 11 attending elementary school, to science, technology, engineering and mathematics (STEM) through educational robotics.

The term educational robotics indicates all those educational activities that involve the design, creation, implementation and programming of robots that are, in this context, machines “capable of carrying out a complex series of actions automatically, especially one programmable by a computer”<sup>1</sup>.

During the ROBOESTATE course, educational robotics activities were proposed together with visits to an ICT research center and to the automated warehouse of a local company, and with some video-conferences proposing role models (i.e. women researchers working on developing innovative robots or teaching robotics).

Through questionnaires proposed to students and to their parents, we looked for answers to two research questions (RQ). RQ1 is: May a course designed like ROBOESTATE encourage students, in particular female students, to pursue a STEM career? RQ2 is: Did parents’ opinions about STEM careers for their daughters/sons change after ROBOESTATE, especially for those who saw STEM careers as not practicable and/or not desirable?

## 2. Context

In 2015, the Italian Cabinet’s Equal Opportunity Department published a call for projects named *STEMs are learned in summer*. The initiative provided funding for projects aiming at the development of in-depth studies in scientific subjects (mathematics, scientific and technological culture, information technology and coding) to be carried out during the summer, targeting elementary and middle school students, mainly female students. The initiative stemmed from the

<sup>1</sup> en.oxforddictionaries.com/definition/robot.

need to overcome the stereotypes and prejudices that feed the knowledge gap between female and male students with regard to STEM subjects, as part of their studies, as well as professional orientations and choices.

The initiative explicitly required the involvement of both boys and girls. The girls had to be at least 60% of participants but not 100%, because “there is evidence that sex segregation increases gender stereotyping and legitimizes institutional sexism” (Halpern et al., 2011).

### **3. Literature analysis**

#### **3.1 Educational Robotics**

First educational robots, small turtle-shaped devices, appeared in the late 1940s (Walter, 1951). Turtle robots are also associated with the work of Seymour Papert about the Logo programming language (Papert, 1980), which was a tool to improve the way children think and solve problems.

Since then, several studies have demonstrated the effectiveness of educational robotics on the development of soft skills in children (see for example the recent studies by Truglio, Marocco, Miglino, Ponticorvo, & Rubinacci, 2018, or by Rubinacci, Ponticorvo, Gigliotta, & Miglino, 2017).

Also, many studies (see for example Benitti, 2012; Bers, 2007; Druin & Hendler, 2000; Resnick, 1998) demonstrate the effectiveness of educational robotics in learning concepts related to STEM disciplines. Projects based on the use of educational robotics as a means to raise interest and enthusiasm for technical subjects in students, especially in girls, have been successfully implemented (Bredenfeld & Leimbach, 2010; Khine, 2017). Research studies (Kim et al., 2015) report on the fact that robotics courses also positively change teachers’ attitudes and engagement towards STEM.

However, the influence of robotics courses on students and, above all, on girls’ career preferences has not been sufficiently investigated (Merdan, Lepuschitz, Koppensteiner, & Balogh, 2016).

### **3.2 Girls and STEM education**

There are several reasons behind the educational actions that aim to increase the number of boys and girls who choose STEM education.

First, a background in STEM entails greater chances to find a job. Indeed, in the United States for example, employment in STEM-related jobs grew much faster (24.4%) than employment in non-STEM areas (4.0%) over the decade 2005-2015, and STEM-related jobs are projected to continue to grow (Noonan, 2017a). Secondly, being employed in STEM increases the chances for a high-paying job. In the United States for examples, in 2015 STEM workers earned 29% more than non-STEM workers. Moreover, even if a STEM degree holder does not work in STEM, he/she can expect a 12% higher salary compared to non-STEM degree holders (Noonan, 2017a). This is true for women too: in the United States in 2015, women with STEM-related jobs earned 35% more than comparable positions filled by women in non-STEM jobs and, in general, the gender wage gap is smaller in STEM jobs than in non-STEM jobs (Noonan, 2017b).

Nevertheless, men still prevail among STEM graduates in higher education, as data show. For example, in the European Union, women accounted for less than half (42.2%) of tertiary education graduates in STEM in 2015 (Eurostat, 2017); in the United States, women make up only about 30% of all STEM degree holders, even if nearly as many women hold undergraduate degrees as men overall (Noonan, 2017b).

Globally, women account for less than a third (28.8%) of those employed in scientific research and development (UNESCO, 2017). Moreover, women are less likely to enter STEM careers around the world (United Nations Educational, 2017) and, when they do, they are more likely to leave STEM careers early (Hewlett et al., 2008).

### **3.3 Parental influence on children's higher education and career aspirations**

The career choice process occurs throughout the entire life cycle. However, especially in the case of quantitative professions like engineering, decisions must be made early in the life cycle, when select-

ing college majors. Research showed that the academic and career aspirations and choices of children and adolescents are gender-typed (Ceci & Williams, 2010; Correll, 2004). Males are more likely than females to be enrolled in advanced-level math and science elective classes (AAUW, 1992), even if several recent studies show no gender differences in middle or high school students' math and science abilities (National Center for Education Statistics, 2001; Catsambis, 1994).

Many factors have been identified as contributors to gender differences in career aspirations and achievement. Although peers seem to influence the development of gendered career aspiration and attainment (Fabes et al., 2014), the role of parents appears to be more relevant (Adya & Kaiser, 2005; Bask, Ferrer-Wreder, Salmela-Aro, & Bergman, 2014; Bleeker & Jacobs, 2004; Eccles, 2009; Galdi, Mirisola, & Tomasetto, 2017; Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005; Polavieja & Platt, 2010; Rampino & Taylor, 2013). Gender beliefs associated with mathematics bias judgments of mathematical competency and, consequently, influence career-relevant choices (Correll, 2001). According to the Eccles et al. (1983) model, the messages parents provide to their children include information regarding the values they attach to various activities, such as math and science, and are often based on parents' perceptions of their children's abilities. Based on their parents' messages, children construct their own self-perceptions and interests, integrate these beliefs into their self-systems, and then use such beliefs in future task choices, such as choosing a college major (Jacobs & Eccles, 2000). When parents hold conventional gender stereotypes, they are more likely to be inaccurate about their child's ability and interests and to hold gender stereotypic attributions about their child's academic performance (Eccles, 2009). Such inaccuracies can contribute to differential parent-supported experiences for boys and girls (Eccles, 2009). Such gendered experiences and messages may undermine girls' confidence in their own mathematics abilities and interest and thereby enhance the probability that young women who are quite skillful at mathematics decide not to pursue advanced education and careers in mathematics-related fields (Eccles, 1987).

## 4. Method

### 4.1 Participants

The participants (Tab.1 and 2) included:

- 25 elementary school students (14 girls [56%], 11 boys);
- age range: 8 to 11, mean: 9.32 and SD: 0.95;
- 11 students were attending 3<sup>rd</sup> grade, 9 4<sup>th</sup> grade and 5 5<sup>th</sup> grade.

**Table 1.** Distribution of invited students

Class Type	Female (%)	Male (%)	Total
3 <sup>rd</sup>	30 (55%)	25 (45%)	55
4 <sup>th</sup>	36 (53%)	32 (47%)	68
5 <sup>th</sup>	24 (50%)	24 (50%)	48
TOTAL	90 (53%)	81 (47%)	171

**Table 2.** Distribution of accepted students

Class Type	Female (%)	Male (%)	Total
3 <sup>rd</sup>	8 (73%)	3 (27%)	11
4 <sup>th</sup>	5 (56%)	4 (44%)	9
5 <sup>th</sup>	1 (20%)	4 (80%)	5
TOTAL	14 (56%)	11 (44%)	25

Participants were all students coming from two elementary schools in the same region, members of the same school district. They were recruited in the following way: before the end of the school, the director of the school district informed the families of all the 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> graders of the two involved schools about the summer camp, with a written notice delivered to all students and explaining in detail the aim of the camp and how it was organized. A total of 171 students were informed (see Table 1 for detail about the gender distribution inside the involved classes).

Participation was voluntary and free of charge. Due to the location and other organization constraints, twenty-five positions were available in total, of which 15 (60%) were reserved for girls, as asked by the project call (see the Context section). Even if 171 students were invited, only 14 girls and 14 boys asked to participate. All the girls, corresponding to 56% of the total available seats, were accepted whereas only 11 males were accepted and they were selected by random sample (see Table 2 for detail).

#### **4.2 Procedure**

Our summer camp consisted of a two-week robotics course (40 hours in total). The course design has been summarized in Table 3. On the first day of the camp, after some icebreakers, all the students were asked to write their names and their career aspirations on sticky notes; they repeated this activity also at the end of the course.

During the course, students worked in groups. In each group, we assigned students having attended the same grade level, where possible: we formed six groups of two female students and one male student, one group of two female students and two groups respectively of three and two male students. When possible, for same grade students, we organized gender-mixed groups to favor the development of collaboration among opposite sex students (Bennett & Dunne, 1991; Gillies & Ashman, 1996; Panitz, 1999).

Most of the time (66%), except for the two days when they visited local companies, students were engaged in robotics activities, which involved both building robots and programming them. Students visited a research center in the middle of the first week and the automated warehouse of a local company in the middle of the second week.

Students would also reflected on robotics (a) during common brainstorming activities, (b) by drawing robots, (c) by watching videos showing robots in real life situations or watching films having robots as their main characters, and (d) by attending Skype meetings where they interacted with female scientists who described their research in different robotics fields. Each day, students would write about their activities on a diary.

**Table 3.** The ROBOESTATE design

first day	icebreakers
	collection of information on career aspirations
every day	robotics activities
	video and film watching or role model meetings
	diary writing
once a week	visit to local companies
last day	collection of information on career aspirations
	assessment of software programming skills
	survey for students
	survey for parents

At the end of the last day of the course, students were requested to fill out an anonymous questionnaire (see Appendix 1). The aim of this survey was to gather information on what they had appreciated most about the camp content as well as the organization.

Also parents, both mothers and fathers individually, were requested to take a survey (see Appendix 2). The main purpose of this questionnaire was to gather information about how parents see the professional future of their children.

### 4.3 Material

*Robotics activities.* For these activities, we used two different types of programmable robotics construction kits: the LEGO® WeDo<sup>2</sup> and the LEGO® MINDSTORMS EV3<sup>3</sup>. LEGO® WeDo is designed for children seven to eleven years old. It consists of several LEGO® bricks,

<sup>2</sup> Lego® WEDO [education.lego.com/en-us/products/lego-education-wedo-2-0-core-set/45300](http://education.lego.com/en-us/products/lego-education-wedo-2-0-core-set/45300).

<sup>3</sup> Lego® EV3 [education.lego.com/en-us/shop/mindstorms%20ev3](http://education.lego.com/en-us/shop/mindstorms%20ev3).



one motor, two sensors and a battery powered smart hub, which connects motor and sensors to the computer running the software program that pilots motor and sensors. LEGO® MINDSTORMS EV3 is designed for children aged ten or older. It consists of: a programmable battery powered brick, 2 or 3 motors, several sensors (touch, color, infrared, etc.) and traditional LEGO® bricks. It allows users to create robots that walk, talk, and move as you tell them to do.

*Coding activities.* The robots built by the students were then programmed with two different types of software environments: for programming the robots built with LEGO® WeDo, we used Scratch<sup>4</sup> whereas for programming the robots built with the LEGO® MINDSTORMS we used the Lego® software<sup>5</sup> programming tool.

*Creative activities.* The students designed and then built a physical setting – a town with houses, factories, and a port – using boxes, sheets of paper and colored adhesive tape, where they could test their robots.

*Videos.* The participants watched several short videos, such as: 10 amazing robots that will change the world<sup>6</sup> and Top Amazing Micro Robots<sup>7</sup>. Then, they discussed about and commented what they had seen, together with the instructors.

*Videoconferences.* The participants attended four videoconferences with female role models: researchers, professors and teachers working in the field of robotics.

## 5. Results

### 5.1 Boys' and girls' perspective about their future career

The career aspirations that students wrote on sticky notes at the beginning and at the end of the course are reported in Table 4. When

<sup>4</sup> Scratch: [scratch.mit.edu/](http://scratch.mit.edu/).

<sup>5</sup> MINDSTORM software: [www.lego.com/en-us/mindstorms/downloads/download-software](http://www.lego.com/en-us/mindstorms/downloads/download-software).

<sup>6</sup> [www.youtube.com/watch?v=6feEE716UEk](http://www.youtube.com/watch?v=6feEE716UEk).

<sup>7</sup> [www.youtube.com/watch?v=8\\_-7Ri-tbHY](http://www.youtube.com/watch?v=8_-7Ri-tbHY).

collecting them, we decided to let the children use a free text instead of forcing their answers in a given list decided by adults, because this could have distorted the final result.

A summary of these data is collected in Table 5, where we see that ten students (10 out of 25 [5 out of 14 females and 5 out 11 males]) corresponding to 40% of the participants changed their career aspirations, even if they did not select STEM career only.

**Table 4.** Students' career aspirations

	At the beginning of the course	At the end of the course	Changed (yes/no)	Type of change
F	Policewoman	Policewoman	no	not STEM/not STEM
F	Hip-Hop dancer or Stylist	Hip-Hop dancer, Stylist, but my biggest dream is becoming a perfect robot designer and robot builder	yes	not STEM/STEM
F	Archaeologist	Archaeologist, robot builder, History teacher, singer, robotics teacher	yes	not STEM/STEM
F	Archaeologist	Math teacher	Yes	not STEM/STEM
F	Horse trainer	Horse and dog trainer, singer, pianist i.e. musician, inventor	yes	not STEM/STEM
F	Inventor	Inventor	no	STEM/STEM
F	Gardener and Florist	Gardener and Florist	no	not STEM/not STEM
F	Violinist	Violinist	no	not STEM/not STEM
F	Nursery teacher, staying with young children	Staying with young children	no	not STEM/not STEM
F	Math, Science and Technology teacher; Hip Hop dancer	Math, Science and Technology teacher; Hip Hop dancer	no	STEM/STEM
F	Teacher	Teacher	no	not STEM/not STEM
F	Teacher	Teacher	no	not STEM/not STEM
F	Waiter	Waiter, teacher	yes	not STEM/changed but not STEM
F	Cashier	Cashier	no	not STEM/not STEM

	At the beginning of the course	At the end of the course	Changed (yes/no)	Type of change
M	Regular soldier	Staying in the world of dreams	yes	not STEM/changed but not STEM
M	Train builder	Software Programmer	yes	not STEM/STEM
M	Inventor	Inventor	no	STEM/STEM
M	Soccer player	Soccer player	no	not STEM/not STEM
M	Mechanic	Building a soccer stadium for robots	yes	not STEM/STEM
M	Soccer player	Soccer player	no	not STEM/not STEM
M	Formula 1 driver	Formula 1 driver	no	not STEM/not STEM
M	Mechanic	Mechanic	no	not STEM/not STEM
M	Software programmer	Robot software programmer, Doctor	no	STEM/STEM
M	Doctor	Building robots, Botanist	yes	not STEM/STEM
M	Playing guitar in a band	Playing guitar in a band	no	not STEM/not STEM

*Legend*

STEM/STEM = career ambition/s at the end of ROBOESTATE stayed the same as initial one/s;  
neither is a STEM career

not STEM/STEM = career ambition/s at the end of ROBOESTATE changed compared to initial  
one; the new career ambition is connected to STEM careers

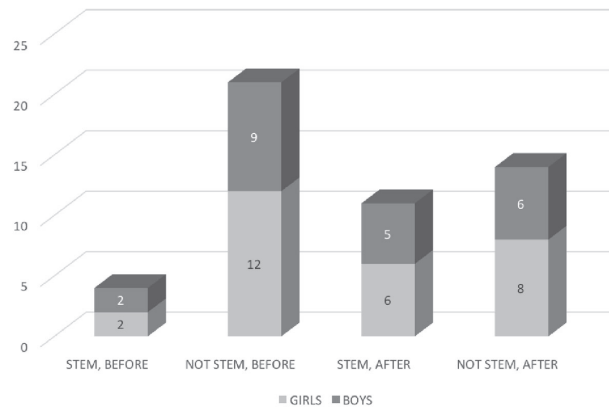
not STEM/not STEM = career ambition/s at the end of ROBOESTATE stayed the same as initial  
one/s; not connected to a STEM career

not STEM/changed but not STEM = career ambition/s at the end of ROBOESTATE changed  
compared to initial one/s, but no to STEM.

Before the course, four students (2 out of 14 females and 2 out of 11 males) wanted to pursue a STEM career (see Figure 1). This preference increased to eleven students (6 out 14 females and 5 out 11 males) after the course. We considered as STEM careers the following jobs indicated by the children: inventor, maths teacher, science teacher, technology or robotics teacher, software programmer, robot designer, and robot builder. It is worth noting that often students have more than one career ambition.

**Table 5.** Percentages of students who changed/did not change their career aspirations

	CHANGED		NOT CHANGED	
F	5	36%	9	64%
M	5	45%	6	55%
TOT	10	40%	15	60%



**Figure 1.** Summary of students' career aspirations, before and after the course

We can conclude that, if before the course our students' career dreams were the popular ones<sup>8</sup> such as athlete, dancer, pilot, teacher, police officer, doctor, etc., after the course they also dreamed to work in robotics.

## 5.2 Students' questionnaires about the design of ROBOESTATE

The students took a survey on the design of ROBOESTATE at the end of the course. Their answers are reported in Appendix 1. Con-

<sup>8</sup> [www.fish4.co.uk/career-advice/8-childhood-dream-jobs-i-grow-i-want/](http://www.fish4.co.uk/career-advice/8-childhood-dream-jobs-i-grow-i-want/).



**Figure 2.** Students' answers to the question Q3.1 "Did you have fun?"

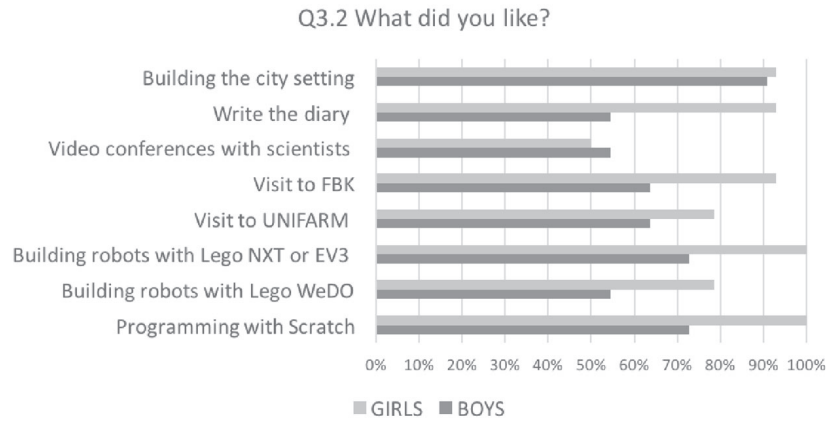
cerning the question whether the course was fun, the majority of students [14 out of 14 females and 10 out of 11 males] answered that they had a lot of fun (see Figure 2 and also Q3.1 in Appendix 1).

In particular, when asked which activities they liked most (see Figure 3 and Q3.2 in Appendix 1), 52%, i.e. 7 girls and 6 boys, answered they liked all the activities (8) proposed.

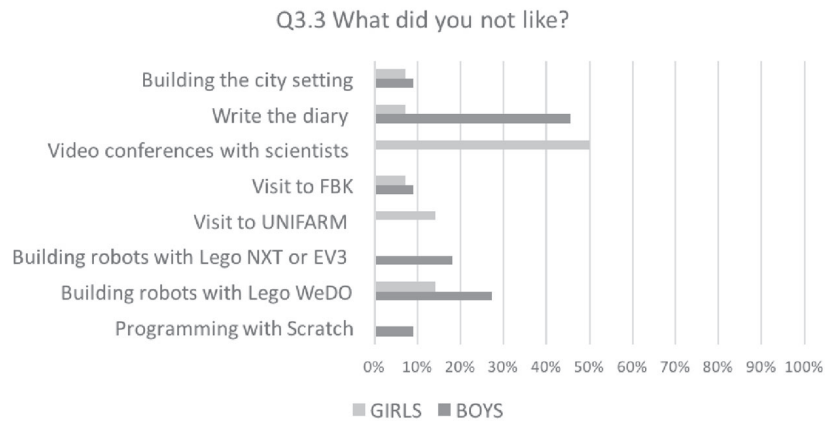
The activity they liked least were the videoconferences with female scientists (see Figure 4 and Q3.3 in Appendix1) (only 7 out of 14 females and 6 out of 11 males liked them). The majority of female students (11 out of 14) liked all the activities, excluding the video conferences. The activity that males enjoyed most was building the city setting (10 out of 11 liked it). What males liked least was writing the diary (5 out of 11).

In general, we see that the students had a lot of fun taking part in our course, with a difference between male and females concerning the specific activities.

As for the groups' composition, all the students approved our decisions of letting them work in groups instead of working individually



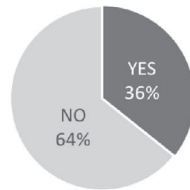
**Figure 3.** Students' answers to the question Q3.2 "What did you like?"



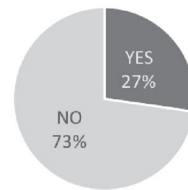
**Figure 4.** Students' answers to the question Q3.3 "What did you not like?"

(see Q4.2 – Appendix 1). The majority of them liked working in gender- and age-mixed groups (see Figure 5 and Figure 6, and also Q4.1 and Q4.3 in Appendix 1).

Q4.1a If you are a female, would you have liked to participate in a course with only females?

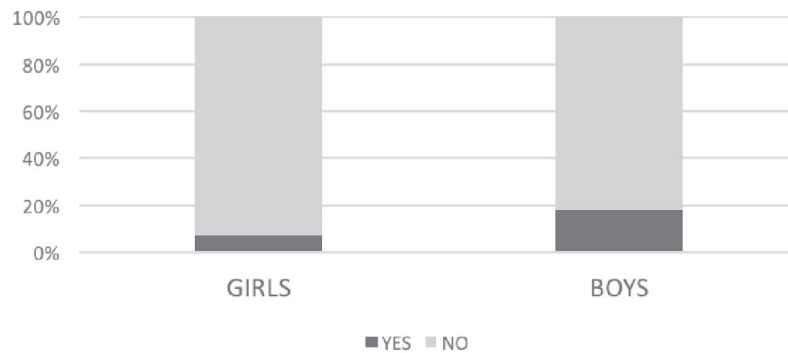


Q4.1b If you are a male, would you have liked to participate in a course with only males?



**Figure 5.** Female students' answers (on the left) and male students' answers (on the right) to the question Q4.1 on the gender composition of the working groups

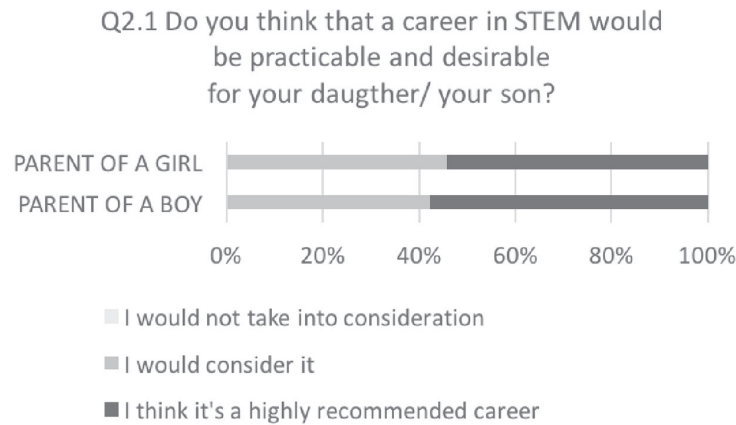
Q4.3 Would you have preferred working with only kids your age?



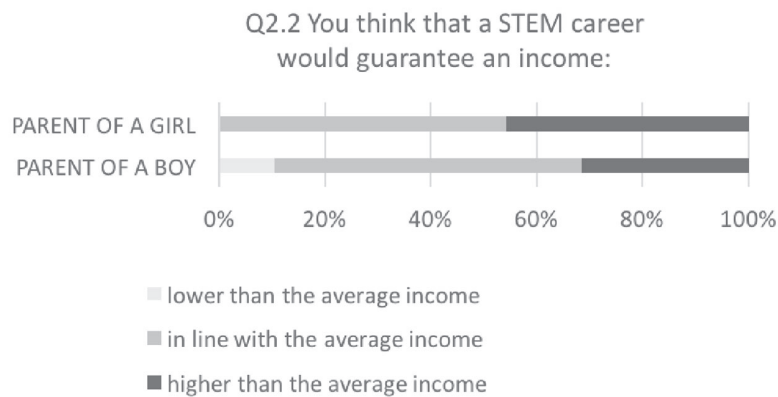
**Figure 6.** Students' answers to the question Q4.3 on the age composition of the participants

### 5.3 Parents' answers to the questionnaire about STEM career desirability

We asked both parents for each participant to take the survey. The answers are summarized in Appendix 2. In total, the involved parents were 50, and we obtained answers from 43 of them, i.e. 86%; 24 were



**Figure 7.** Parents' answers to the question on the desirability of a career in STEM



**Figure 8.** Parents' answer to the question on the income of a career in STEM

a girl's parents and 19 a boy's parent. Twenty-four of them think that a career in STEM is a highly recommended career for their daughter/son (see Figure 7 and Q1.2 in Appendix 2) whereas 19 would consider recommending it.

Forty-two think that a job in STEM is in high demand (see Q2.1 - Appendix 2). Twenty-four of them think that a STEM job earns one an



income in line with the average income of graduates (see Figure 8 and Q2.2 in Appendix 2), whereas 17 think that a STEM career would translate into a higher income than the average income of graduates. Forty parents (93 %) think that ROBOESTATE has made their daughter/son think that it is practicable and desirable to start a career in the technical-scientific field.

## **6. Discussion**

As a premise, let us say that, due to the small number of students and parents involved, our results do not reach statistical significance. However, we believe that our results are promising and may be useful to those interested in designing effective courses to promote STEM careers using educational robotics.

Our first research question was: May a course designed like ROBOESTATE encourage students, in particular female students, to pursue a STEM career? Our results seem to support a positive answer. Indeed, before the course, only two females were considering pursuing a STEM-related job (an inventor and a Math teacher), whereas after the course six females expressed their preference for a STEM career and another girl, who before the course wished to become a waiter, after the course added teacher to her career aspirations. Among new ones, girls cite robot designers, robot builder, robotics teacher, and inventor. Even if we considered a small group of participants (14 girls), we can say that our results (see Tables 4, 5 and Figure 1) confirm the literature findings, i.e. we can say that an educational robotics course may raise interest in STEM, as reported in other research studies (see for example Bredenfeld & Leimbach, 2010, or Khine, 2017). Our results (see Tables 4, 5 and Figure 1) seem to demonstrate that not only some of the girls attending ROBOESTATE changed their minds about STEM careers, but also several boys did. Overall, after our course, 44% of our students (6 girls and 5 boys) expressed their intention to pursue a STEM career compared to 16% of students (2 girls and 2 boys) before the course. Among the new career dreams, boys also include software programmer. These data show that our re-

sults confirm the literature findings (see for example Khine, 2017) as reported in the Literature Analysis Section.

The second research question was: did parents' ex-post opinion about STEM careers for their daughters/sons change, especially in the case they ex-ante saw STEM careers as not practicable and/or not desirable? In general, after the analysis of the parents' questionnaires (see Appendix 2), the answer would be no. Indeed, only 6 parents (14%) out of the 43 who completed the questionnaire, say that after the ROBOESTATE course they changed their opinion about the desirability of a STEM career for their daughters or sons. These parents say that before the course they thought STEM careers were to be discouraged, while now they think they are desirable. We think this may be due to the appreciation of the course showed by their children and because, talking with their children, they learned more about STEM careers. The majority of parents (36 out of 43, i.e. 84% of those who took the survey) did not change their opinion as they thought that a STEM career was desirable even before the course started. This conviction could be explained by the fact that while the letter of invitation was sent to a large population of families, participation to ROBOESTATE was voluntary and this fact may have introduced an element of distortion in the sample.

## **7. Conclusion and Future Work**

This paper presented the analysis of the effects of the ROBOESTATE project, a summer camp aimed at introducing students, especially female students, aged 8 to 11 to STEM through educational robotics activities. Our analysis focused on two main research questions: (RQ1) May a course designed like ROBOESTATE encourage students, in particular female students, to pursue a STEM career? (RQ2) Did parents' opinions about STEM careers for their daughters/sons change after ROBOESTATE, specifically in the case they ex-ante saw STEM careers as not practicable and/or not desirable?

First, we offered a review of the literature related to our research topic. Then, we described in detail the ROBOESTATE course and the method we followed to collect the data for our analysis. Finally, we

reported the qualitative and quantitative analysis of our data and the answers to our research questions.

We concluded that a ROBOESTATE-like designed course increases the interest level of both boys and girls in STEM careers. In general, both boys and girls appreciated the proposed activities. What males liked least was writing the diary (5 out of 11). This may be due to the fact that they were tired around the time they were supposed to write.

As for our future work, we are planning on working with a larger number of participants, especially girls. We will also propose a questionnaire to the involved parents at the beginning of the course too, to be able to better understand whether the course changed their opinions about desirability of a STEM career. We will also investigate the research question: do elementary school students benefit more from activities organized in single-gender or in mixed gender groups?

Also issues related to accessibility will be considered. For example, we will investigate how effective robotics activities for blind students can be organized.

Finally, we would like to provide teachers with support on how to approach educational robotics and listen to their opinions on its practicability and effectiveness in the school setting.

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