Teacher and student views on educational robotics:
The Pan-Hellenic competition case

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Abstract: The present work is an observational study recording the teachers’ and students’ attitudes from the Pan-Hellenic Educational Robotics (ER) competition. The study investigates the benefits of students’ involvement with robotics regarding skills, motivation and learning. Additionally, it is researched whether ER should be introduced in the compulsory curricula. A qualitative methodology was used with teachers. Although the sample was relatively small, the results were quite homogeneous showing a very high level of engagement and motivation of teachers and students. A mainly quantitative methodology was used to gather data from students. The results show that there are numerous benefits for students: they seem to increase their collaboration, problem solving and creativity skills; understand STEM concepts in computer science and engineering, and gaining programming knowledge in particular. Also, most of the teachers and many of the students consider that ER should be part of the compulsory curriculum. Under certain conditions, ER could be an essential part of the school program, as it can bring together young people from all over the world to learn and develop important 21st century skills.

Keywords: Educational Robotics, Programming Learning, Teachers’ perceptions, Students’ attitudes

1. Introduction

Past research has shown that early involvement with Educational Robotics (ER) can increase students’ motivation for STEM (Science, Technology, Engineering and Mathematics) related education at the secondary and tertiary levels and make Computer Science Education (CSE) more attractive to students [1].

This article is part of a study conducted in Greece on alternative teaching methods in Computer Science at elementary and secondary schools. More specifically, the present work collected qualitative and quantitative data on ER in schools, based on teachers’ and students’ opinions after their engagement with the Pan-Hellenic robotics competition. Our goals in this study were to: (a) focus on students’ involvement with robotics during their preparation for the national competition, (b) focus on teachers’ and students’ attitudes; (c) investigate different aspects of skills, learning and motivation. The work presented here is loosely based on and forms a major extension of paper [2], which was presented at the WiPSCE 2016 (the 11th Workshop in Primary and Secondary Computing Education).

The challenge of how to motivate students to engage on creative activities in CS is still very high. In particular, our research is intended to fill this gap by conducting an empirical investigation that enables both students and teachers to efficiently participate in activities through Educational Robotics (ER). Our research follows a two-phase process (Figure 1). In the following sections, phases 1 and 2 will be presented in more detail. The paper is structured as follows: Section 2 provides the background of the study and a review of related literature. Section 3 deals with the research questions
and the context of the study adopting the Darmstadt model. Next, in section 4 (methodology), the procedure and design, the participants and applied instrumentation of the study are described. The findings of the study are presented in section 5 and they are discussed in section 6. Finally, section 7 presents conclusions, limitations and future work.

Figure 1. Phases of research study.

2. Background

2.1. ER and CSE

Many types of approaches and activities have been proposed for introducing CS principles and concepts to children [3-5]. As Armoni, et al. [6] report in their study, activities in CS fall into three main categories: 1) Kinesthetic activities, that do not use a computer, 2) Visual programming environments, where students create programs by using simple interfaces, and 3) Robotics, activities that are widely used to introduce science and technology to young students. In addition, alternative learning approaches are considered essential in bridging the gap between the school curriculum and the scientific nature of STEM concepts [1]. The present work focuses on ER, a teaching method that relies on the use of robots for teaching purposes [7].

Being an alternative learning approach, educational robots are known to support constructivist learning and provide the opportunities for the personal construction of knowledge and meaning [8]. ER’s theoretical and pedagogical background is based on the field of Constructivism and the works of Piaget and Papert, where learning is viewed as a process during which learners construct their personal meaning through active participation [9-11]. The educational robots LEGO® Mindstorms® are directly related to the work of Papert and are widely used in various educational settings to teach programming and engineering [12]. They are also used to teach several other skills. For example, LEGO®es were used to teach students to be independent and achieve self-directed learning [13]. LEGO® Mindstorms® have been successfully used with students of different ages to support CSE from young children [14] to college students [15]. Interestingly, even when the same activities are used for primary school students and final year IT students, significant learning benefits were found for both [16].

ER can offer a unique alternative to traditional teaching methods by integrating STEM-based applications in CSE. Robotics seem appropriate for introducing CS to young people, since users can directly see the output of their programs and not simply write code or see virtual characters on a screen [17]. Finally, robots enable students to engage with CS concepts and programming in a fun and creative fashion, increasing interest levels [18], motivation, problem-solving and student collaboration [19].

2.2. ER and Competitions

Many types of approaches and activities have been proposed for introducing CS principles and concepts to children. Most educational robotic practices take place in the middle and high school levels, where, over the last years, a number of competitions are held and many students participate.
These competitions provide educational settings that increase motivation [20], engagement [21] and even training in specific domains like Human-Robot interaction [22]. Their use has grown in popularity as demonstrated by the growth of national and international robotics competitions, such as: World Robot Olympiad (WRO™)¹, FIRST Robotics Competition (FRC)², Boosting Engineering, Science, and Technology (BEST)³, VEX Robotics (VEX)⁴, RoboCupJunior⁵ and First LEGO League (FLL)⁶.  

Benitti [23] explored the educational potential of robotics in schools by conducting an extensive systematic literature review and suggested that educational robotics usually acts as an element that enhances learning. Moreover, many of the robotics courses offered at schools all over the world nowadays, aim for participation in ER student competitions [24]. A previous study from Apiola, et al. [25] evaluated the impact of a robotics competition on secondary school students. The results showed improved students’ interest for STEM, increased self-confidence and improved skills and problem solving abilities. Varnado [26] investigated the effects of a technological problem solving activity during a FLL competition by researching students’ problem solving styles and performances. Student participants showed significant increases in confidence, overall technological problem solving styles, problem clarification, developing a design, evaluating a design solution, and overall technological problem solving performance in only eight weeks. Welch [27] examined students’ attitudes with respect to the social implication of science, through their involvement with robotics during a competition. Students showed gains in positive attitude toward science. More recently, Kandhöfer and Steinbauer [28] investigated the impact of educational robotics on technical skills, social skills as well as on science related attitudes and interests of pupils from different schools in Austria and Sweden. Results indicate significant intervention effects for three sub-scales (mathematics and scientific investigation, teamwork, social skills) as well as for two main categories (technical skills and soft skills/social aspects). Another study [29] provides evidence that there is a strong need for the expansion of ER competitions, since they are particularly beneficial for low-income communities and minority youth.  

Moreover, all these studies have measured the impact of participation in robotic competitions through a student perspective. For the present study, data were collected from all the participants, both teachers and students of the Pan-Hellenic robotics competition of WRO™ Hellas (Organization for Educational Robotics, Science, Technology and Mathematics). Previous works focused on the evaluation of competitions investigating the long-term impact of robotics on student participants [29,30]. This work focuses on teachers’ and students’ perspectives in addressing questions about robotic education. Diethelm, et al. [31], emphasize the importance of the teachers’ perspective on such competitions, since their opinion is of significant importance in educational research. Finally, there are certain factors that affect students’ motivation to engage with ER activities like ease of use and perceived usefulness, together with the intensity of the educational experience they offer [32]. In this

⁵ RoboCup Junior: http://rcj.robocup.org/, last accessed 09/06/2017.  
light, ER competitions seem to offer the required elements for intensifying the experience and thus increasing learning motivation. However, this claim remains to be confirmed in the present work.

3. The study

3.1. Research Questions

For the purposes of our study, we posed the following three research questions:
RQ1: What are the benefits of students’ involvement in an ER competition, as perceived by both teachers and students, relating to skills and motivation.
RQ2: Can ER be used to teach basic STEM principles like programming and engineering, in the Greek educational system?
RQ3: Should ER be introduced in the Greek compulsory curricula? And if so, on what level?

3.2. Research Context

Recently there has been an attempt to create a holistic framework for CSE in schools, including the educational systems of different countries. The developed framework aims at presenting the diverse factors that affect CSE, in order to be able to compare and transfer findings from different areas and apply an investigation in an international context. This framework is known as the Darmstadt model and is presented in [33]. Within the framework of the Darmstadt model, Greece was represented as an extensive case study showing practices regarding CSE in Greek education [34]. The present study focuses on a Greek competition, Greek school curricula respectively. We wish to approach the issue of educational robotics within this framework in order to provide additional information and make this study more usable into an international context. Therefore, the following paragraphs discuss the main axes of the Darmstadt model, within the Greek educational context. However, a complete analysis of the Darmstadt model is outside the scope of the present work and for this reason, only a short description will follow.

In the present observational study, questionnaires were collected from teachers/coaches and students that participated in the Pan-Hellenic educational robotics competition 2015 of WRO™ Hellas on the 3rd of October 2015. The Range of Influence is therefore covering the whole of Greece, including primary and secondary education. The Educational Relevant Areas axes, following the Darmstadt model, are as follows:

Socio-cultural factors: CS courses are not core curricular courses in Greek primary and secondary education. The engagement with ER is an extracurricular activity. In addition, both CS and ER are considered secondary educational features by the wider Greek public [3].

Policies: Due to the current economic crisis in Greece, there is a lack of CS teachers and laboratory infrastructure, mostly in provincial schools. ER require financial resources that are not available in many cases (will be described below).

Teacher Qualifications: CS teachers are highly qualified with University degrees. The participating sample is described in the method section in detail.

Curriculum Issues: CS courses are taught only one hour per week in grades seven to nine. Moreover, programming is taught for first time in the ninth grade through Logo programming language. In tenth grade (first year of senior high school in Greece), CS is an optional course. In eleventh grade, it is taught an hour per week and finally in the last year of secondary education, it is taught just in specific scientific fields. Educational robotics are not a part of the schools’ CS curriculum. In Greek primary education CS is taught in selected schools with reformed curriculum (called EAEP: FEK 804/2010)

Examination/Certification: CS courses in Greek primary and secondary education do not lead to any certifications.
Motivation: In the Greek educational system, students finishing the secondary education, take national exams in order to enter higher education. A programming course is prerequisite to enter economic and computing departments.

Teaching methods: Curricular activities related to CSE in Greek schools usually follow traditional teaching methods like lectures, fixed exercises and exams. ER require hands-on experiences. All activities take place outside school hours and on a purely voluntary basis from all participants (students and teachers).

4. Methodology

The main purpose of this study is to investigate the impact of robotics, in particular LEGO® Mindstorms®, on students' learning, motivation and skills in education. Furthermore, the study intends to present Greek teachers' and participating students' attitudes towards robotics in education.

4.1. Procedure and Design

The 7th PanHellenic ER competition was organized by WRO™ Hellas. The competition was held in Athens in October 2015 (Figure 2) under the auspices of the Ministry of Education and there were over 300 students participating from all over Greece. The teams that took part at the competition prepared several months earlier, outside school hours and purely voluntarily.

![Figure 2. Photos from the 7th PanHellenic Educational Robotics competition.](image)

The competition followed the official rules set by the WRO™ Hellas in order to distinguish the teams that would participate in the Robotics Olympiad. In order for a team to join the competition it should have passed through the regional competitions that were organized all over the country between May and September 2015. The theme of the competition was, as in the Olympics, the “Robotic explorers”, under which students were asked to build a robot to explore different environments (e.g. seabed for elementary schools or the mountains for the senior high schools).

As for the robots that were used, WRO™ allows only the use of the LEGO® Mindstorms® robotics platform for WRO™ Regular Category (Elementary, Junior High, High School), and this policy is in place to ensure equal opportunities for all participants (Figure 3). The competitions aim to challenge the participants to use their creativity to construct and program autonomous robots and the LEGO® Mindstorms® platform is found to be the most appropriate.

An online survey was carried out after the competition, in November 2015. The survey was targeting teachers and students that participated in the Pan-Hellenic ER competition of WRO™.
In order to address the research questions this study relied on qualitative and quantitative data collected by the questionnaire.

4.2. Participation

For phase 1, all participants were teachers leading different competing groups at the Pan-Hellenic Educational Robotics competition of WRO™ Hellas. Each teacher could be the instructor-coach of one or more teams. Eighteen completed questionnaires were received from teachers. Furthermore, 30 questionnaires were collected from participating students. Table 1 lists the profile and expertise of the 18 teachers, from whom N=6 (33.3%) were females and N=12 (66.7%) were males. The majority of the participants had a higher education IT background and most of them had a long teaching experience.

Table 1. Profile of the 18 participating teachers.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Specialty</th>
<th>Groups</th>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>CS</td>
<td>5</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T2</td>
<td>CS</td>
<td>2</td>
<td>&gt; 5 years</td>
</tr>
<tr>
<td>T3</td>
<td>Mathematician</td>
<td>1</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T4</td>
<td>CS</td>
<td>4</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T5</td>
<td>Primary Teacher</td>
<td>1</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T6</td>
<td>CS</td>
<td>3</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T7</td>
<td>Science/CS</td>
<td>1</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T8</td>
<td>CS</td>
<td>5</td>
<td>&gt; 5 years</td>
</tr>
<tr>
<td>T9</td>
<td>CS</td>
<td>5</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T10</td>
<td>CS</td>
<td>4</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T11</td>
<td>Primary Teacher</td>
<td>4</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T12</td>
<td>CS</td>
<td>1</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T13</td>
<td>CS</td>
<td>1</td>
<td>&gt; 5 years</td>
</tr>
<tr>
<td>T14</td>
<td>Science</td>
<td>5</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T15</td>
<td>CS</td>
<td>3</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>T16</td>
<td>CS</td>
<td>5</td>
<td>&gt; 5 years</td>
</tr>
<tr>
<td>T17</td>
<td>Electrician</td>
<td>2</td>
<td>&gt; 10 years</td>
</tr>
</tbody>
</table>
Most instructors participated in the competition with more than one team. It seems that teachers are highly motivated to participate in such activities, since each team’s preparation requires many resources and personal time from the instructor.

In addition, most teachers met at least once a week with their students in order to practice with robots. Most of the meetings took place in schoolrooms like the computing labs or the school libraries.

For phase 2 participants were students that participated in the ER competition. From the participating students, 24 were males and 6 females, from 13-18 years of age. In addition, the sample included one university student, 19 senior high school students, 6 junior high school students and 4 primary school students. The majority of students reported very high marks on school courses and 22 of them had top scores in school (average between 18.6-20, 20 being the top mark) and 4 students reported having high marks (15.6 - 18.5). Primary school students do not receive marks in the Greek educational system.

4.3. Questionnaires

The process of developing the questionnaires was done in cooperation with an expert in the field of psychology respecting general rules of questionnaire-design [35-37]. Furthermore, the questionnaires combine different standardized assessment tools as well as survey instruments, which have been validated and/or applied in previous studies [38-44]. As described in those studies experts reviewed and helped to validate the assessment instrument’s content. For the purposes of our study, those assessment tools have been adapted and modified in some cases. Item reliability was checked with Cronbach’s α indicators, the result of the test revealed acceptable indices of internal consistency in all the factors. The questionnaires ran through several refinement and improvement steps (review by teachers and pedagogues). Since the present study had specific goals, the instrument used for data collection can be only used here. If, however, we wish to extend its use, more questions need to be reviewed and considered in order to have a general character.

For Phase 1, the instrument for assessing teachers’ attitudes/opinions was 22 items mostly open-ended questionnaire (OEQ) but also included some multiple-choice questions (MCQ)7. The questionnaire is structured around five main sections (Parts) and is divided into relevant sub-sections (from a to d) that briefly describe the questions:

Teachers Questionnaire (A)

Part A: Demographic/background information (5 items, MCQ)
(a) Background factors: teaching experience, teacher specialty
(b) Statistical information: age, gender, school

Part B: Competition Preparation (8 items, MCQ/OEQ)
(a) Funding resources: money for the robots, supplies and travel expenses
(b) Difficulties: problems that teachers faced during the preparation time for the national ER competition

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7 Teacher questionnaire can be found online at goo.gl/cAEOi9 (in Greek).
(c) Instructor-coach: number of participating teams, members
(d) Meetings with the students: how often, when and where

**Part C:** Students’ Motivation/skills (2 items, MCQ/OEQ, [38-40])
(a) Motivation: what motivates students most in their involvement with ER
(b) Skills: skills that students acquired from their involvement with ER

**Part D:** Students’ Evaluation (2 items, OEQ, [40,42])
(a) Programming: what did students learn as far as programming is concerned
(b) Engineering: what did students learn as far as engineering is concerned

**Part E:** Attitudes (5 items, MCQ/ OEQ, [40,44])
(a) Curriculum: ER in compulsory education, to what level, STEM education
(b) Society: parents’ attitudes towards ER, technological convergence
(c) Open source robots: robots based on open source software, advantages, disadvantages, other robotics competitions

Similarly, for phase 2 the instrument for assessing student opinions was a 19-item questionnaire including mostly Likert Scale Questions (LSQ), but also some Open-Ended (OEQ) and some Multiple Choice Questions (MCQ). The questionnaire is structured around five main sections (Parts) and is divided into relevant sub-sections that describe briefly the questions:

**Students Questionnaire (B)**

**Part A:** Demographic/background information (4 items, MCQ)
(a) Statistical information: age, gender, school level, overall school marks

**Part B:** Programming and Technology Skills (2 LSQ items, [40,42])
(a) Programming skills (1 item, [43]): Programming languages, visual programming, pseudo-languages
(b) Technology preferences (1 item): computer games, technology, computer science, robotics

**Part C:** Robotics-Competition (2 items, [38-40,42])
(a) Ease of use (1 item LSQ)
(b) Competition preparation difficulties (1 item OEQ)
(c) Competition motivation (2 items LSQ): possible participation in the Olympiad, future engagement

**Part D:** Motives-Benefits (6 items, [40,42])
(a) Benefits (4 items LSQ): learning, entertainment, problem solving, cooperation, creativity, discipline, programming, engineering
(b) Likes-Dislikes (2 items OEQ)

**Part E:** Attitudes-Opinions (3 items LSQ, [40,44])
(a) Curriculum: ER in compulsory education
(b) Society: parents’ attitudes towards ER, gender differences

4.4. Data Collection and Analysis

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* Student questionnaire can be found online at goo.gl/FE1hw5 (in Greek).
For the first Phase of our study, the data collected were teachers’ responses to Questionnaire A. The questions were designed to investigate different aspects of students’ learning, motivation and creativity through teachers’ perceptions. The sampling process was done randomly from online media rather than making a specific selection amongst teachers. An invitation was sent via WRO™ Hellas official Facebook page9 and also via WRO™ Hellas official forum10, just a few days after the PanHellenic competition. The qualitative data (Phase 1 about teachers) were coded in an inductive manner with respect to emerging themes, following the guidelines in Mayring [45]. After the teachers’ responses were collected, we proceeded with a content analysis. Two researchers read all the responses, coding important keywords until categories emerged from similar codes. The themes were then grouped to facilitate further analysis.

For the second Phase of our study, the data collected were students’ responses to Questionnaire B. The questions were designed to investigate different aspects of students’ learning, motivation and creativity through their attitudes towards ER. The sampling process was done in a similar way with phase 1 but this time teachers forwarded the link to the questionnaire to their students. This observational study had only closed type questions and therefore the data collected were quantitative. Yet, all variables were categorical and therefore a chi square test was performed. The significance level was set at .05 based on statistical guidelines11.

5. Findings

In this section, we describe our findings. First the teacher data from phase 1 are analyzed (subsections 5.1 to 5.4) and then the student data from phase 2 are presented (subsections 5.5 to 5.8). Although the sample was relatively small (N=18 teachers and N=30 students), the results were quite homogeneous and thus it allowed us to present the findings in a grouped approach.

5.1. Teachers: ER Motivation and Skills acquired (RQ1)

As far as motivation from students’ involvement with robotics is concerned (Table 2), all teachers are convinced that students enjoyed robotics and that is viewed as the best motivator. Characteristically, teacher T17 replied:

T17: I think the main benefit of educational robotics is the motivation that children acquire from learning by doing (something) in a fun way.

Furthermore, many teachers responded that students were motivated by the novelty and challenge that robots offer (8 cases). Indicatively, teacher T2 wrote:

T2: Students most liked the fact that they dealt with something innovative and challenging throughout the competition. They were motivated by the fact that they could create something from nothing.

Some teachers also believed that students were motivated by the collaborative nature of the activities during the preparation time for the competition (4 cases). Certain teachers’ responses were:

T4: They were excited by the value of teamwork, a concept that although taught in a school course i.e. Project course, is not easily understood.

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T13: Students enjoyed working in groups with their classmates. Collaboration and mutual support are essential ingredients for such activities. Actually, my students collaborated with harmony and in a way I had not expected.

Additionally, the fact that ER offers direct outcomes and students can directly see the result of their activities, was mentioned 3 times (Table 2). Teacher T15 responded:

T15: My students were motivated to use robots because of the fact that they had direct feedback of their actions and the possibility of immediate correction connected to real world problems.

Yet, three more teachers thought that students were motivated by the nature of robotics, since they participated in a highly creative process. Teacher T18 mentioned:

T18: Students were inspired by the challenge of seeking a creative solution to a complex problem.

Other responses were also mentioned like:

T4: The involvement with robotics made students feel special and different in a positive way compared to other students.

T12: … the possibility to travel to other places in order to participate in an international competition; and the competitive atmosphere that was created for the national competition.

Table 2. Motivation: most commonly occurring themes.

<table>
<thead>
<tr>
<th>Motivation</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment</td>
<td>18</td>
</tr>
<tr>
<td>Novelty/Challenge</td>
<td>8</td>
</tr>
<tr>
<td>Collaboration-Team working</td>
<td>4</td>
</tr>
<tr>
<td>Relation to real world</td>
<td>3</td>
</tr>
<tr>
<td>Creativity</td>
<td>3</td>
</tr>
</tbody>
</table>

As far as specific skills are concerned, table 3 summarizes the grouped results from teachers’ opinions. Teachers consider that most students can develop numerous skills from their involvement in such activities. Moreover, everybody mentioned that students improved important skills such as: problem-solving, collaboration and project management. Here are some of the teacher responses:

T11: It was impressive to see primary school students implementing solutions by breaking a problem into sub-problems and trying to find solutions to simpler tasks.

T4: I think the most valuable skill that the students learned was the essence of the team spirit and the need for collaboration. There were tasks that even the better students did not manage to accomplish and the solutions came from collaboration with their teammates.

T3: The participation in the national competition was a huge project itself. My students dealt with matters of planning and monitoring the project in all phases. Together we shaped the goals, we found resources and we created schedules for each phase.

Moreover, most teachers thought that students developed creativity skills, since such responses were mentioned 10 times from different instructors. One of them made the following remark:

T12: The building part of the robot (assembling the LEGO® blocks), required solutions that even I could not think. Students came up with better ideas many times and thus I think that one of the skills that they developed was creative thinking.

Additionally, N=7 teachers estimated that students increased their social skills. Teacher’s T4 answer regarding social skills was representative:

T4: Even more introvert students developed communication and interaction skills after some time.

Finally, some teachers provided extra skills they thought the students gained, as an addition to the above. Their responses included increased self-esteem (N=3 cases), computational thinking (N=3 cases) and self-discipline skills (N=2 cases).
Table 3. Skills: most commonly occurring themes.

<table>
<thead>
<tr>
<th>Skills</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team spirit</td>
<td>18</td>
</tr>
<tr>
<td>Problem solving</td>
<td>18</td>
</tr>
<tr>
<td>Project management</td>
<td>18</td>
</tr>
<tr>
<td>Creative thinking</td>
<td>10</td>
</tr>
<tr>
<td>Social</td>
<td>7</td>
</tr>
<tr>
<td>Computational Thinking</td>
<td>3</td>
</tr>
<tr>
<td>Self esteem</td>
<td>3</td>
</tr>
<tr>
<td>Self-discipline</td>
<td>3</td>
</tr>
</tbody>
</table>

5.2. Teachers: ER Learning STEM concepts (RQ2)

In order to examine if robotics can be used as an alternative to teach CS and STEM concepts, two parts were evaluated: programming and engineering. Those were the two disciplines that the students got involved in whilst working with the robots.

As far as programming is concerned (Table 4), most teachers (N=18), responded that students grasped programming concepts more easily and understood structural programming concepts because of the visual programming language (EV3) that the robots use. This view is demonstrated here in teacher’s T1 response:

T1: With visual programming students understood many programming concepts easily, like variables, loops, switch, etc. They could see things happen and follow up the logic of a program and consequently understand the need to implement structured programs.

Additionally, most teachers (N=14) reported that students learnt basic programming principles. In particular, teachers mentioned that robotics helped their students understand basic principles such as variables, conditions and loops. Most students also created functions with parameters and used arrays in their programs. This impression is shared by teachers T7, T13 and T18:

T7: Students understood very easily the meaning of variables by changing them, comparing them, looping over them and returning their values in one way or another. Overall, they did not learn anything too confusing, just the steps to make things work. But let’s just say that they can create basic programs on their own by now without any previous programming experience.

T13: Robotics is an excellent way to teach repetition structures. The tasks we had to accomplish required to repeatedly process one or more instructions until some condition is met. Most tasks were repetitive, and seeing the robot do what the program said was the best way for students to understand the concept.

T18: My students learned structural programming and the meaning of functions, using them when needed and by changing their input. They also understood the “bug” concept, since many times their programs had logical errors.

From the above, it seems that all teachers (N=18) consider that students understood the “divide and conquer” idea of structural programming.

Finally, most teachers (N=12) thought that students acquired Computational Thinking skills. Teacher T3 made the following remark about programming learning:

T3: Students became familiar with basic algorithmic structures (sequence, selection, and repetition), used variables, logical conditions, nested structures, created procedures with parameters and processed dimensional arrays. They learned to decompose the entire decision making process, and tried to find all possible solutions,
ensuring that the correct decision was made based on the corresponding parameters and limitations of each problem. In other words, they seem to have followed what we call Computational-Thinking process.

Table 4. Programming: most commonly occurring themes.

<table>
<thead>
<tr>
<th>Programming Evaluation</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Programming</td>
<td>18</td>
</tr>
<tr>
<td>Visual Programming</td>
<td>15</td>
</tr>
<tr>
<td>Basic Principles</td>
<td>14</td>
</tr>
<tr>
<td>CT</td>
<td>12</td>
</tr>
</tbody>
</table>

As far as engineering is concerned, 9 teachers believe that students learnt basic engineering principles (Table 5). More specifically, 5 teachers state that their students used the concepts of forces - torque, and friction. Furthermore, 4 teachers consider that students acquired action and reaction principles like the use of gears, acceleration and deceleration and the motion transfer from horizontal to vertical axis. This is what some teachers said:

T6: I believe that by the end of the competition my students were able to describe basic engineering concepts that had to do with the robot structure and movement. They understood the relationship between work, force and power; they used gears, acceleration and deceleration concepts; they tried torque in different settings.

T14: We had to make our robot more flexible to reach the mountains from distance. We used all the possible hardware we could, like motors, sensors and gears but it was also necessary for students to search for better solutions by using their knowledge from physics, like forces and torque and action-reaction principles.

T17: A big part of the competition had to do with robot construction to accomplish the given tasks in a faster and more efficient manner. At that point students had to practice with engineering concepts (forces and torque as well as action and reaction principles) to find the best structure.

Additionally, most of the teachers (N=12) thought that students learned solving construction and assembling matters through the building blocks and the different constructions they had to make. Teacher T5 made the following remark:

T5: Children are familiar with LEGO® blocks and therefore the can use them easily to create solutions that are outside our view.

Nevertheless, the discipline of engineering is extremely broad, and encompasses a range of more specialized fields. Teacher T3 mentioned that although ER can provide excellent opportunities for engineering teaching and learning, there was not enough time to deepen learning in this field.

T3: There were so many things I wanted to give children…If I had more time, I could give more explanations using physical-mechanical and interdisciplinary approaches on the subject. Unfortunately, too much time pressure to catch up dates did not give me the ease to explain it so.

Table 5. Engineering: most commonly occurring themes.

<table>
<thead>
<tr>
<th>Engineering Evaluation</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructions-Assembling</td>
<td>12</td>
</tr>
<tr>
<td>Basic principles</td>
<td>9</td>
</tr>
<tr>
<td>Forces and torques concepts</td>
<td>5</td>
</tr>
</tbody>
</table>
Action-reaction principles

5.3. Teachers: ER Curricula and Attitudes (RQ3)

In order to examine if there is a place for ER in Greek educational system (RQ3), we gathered teachers’ responses. As far as curricula and ER is concerned, it was not surprising that the majority of the teachers (14 out of 18) think that robotics should be a part of the compulsory curriculum (Table 6). Characteristically, teacher T9 reported:

T9: Let’s look to other countries, not to copy their programs blindly, but to ask why we are so far behind. Robotics is a basic course in many educational systems from primary school to university and is inextricably linked with the production-industry. At present, in our country we rely on teachers’ will, who overcome themselves due to lack of structures and resources

However, although the majority of teachers assume that ER is essential in schools, it seems that there are many different opinions concerning at what level it should be introduced. Five instructors would like to see ER in all levels of education, including primary and secondary. Nevertheless, there were some concerns regarding very young students and 4 teachers thought that activities like these should be introduced after the 4th or 5th grade of the primary school. This impression was shared by teacher T11:

T11: The educational robotics should be taught from elementary education. Students can learn cooperation and team spirit from a young age. My view is to start in 4th grade, because children of that age have the maturity for such educational activities.

Finally, it is worth mentioning the view of teacher T3, who claimed that robotics should not be considered a separate discipline:

T3: ER do not need to be introduced as a separate topic in schools but can be a part of an interdisciplinary approach in the teaching of different modules like mathematics and natural sciences.

Table 6. Curriculum: most commonly occurring themes.

<table>
<thead>
<tr>
<th>Robotics in curriculum</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory curriculum</td>
<td>14</td>
</tr>
<tr>
<td>In all levels</td>
<td>5</td>
</tr>
<tr>
<td>Secondary education</td>
<td>5</td>
</tr>
<tr>
<td>Elementary education</td>
<td>4</td>
</tr>
</tbody>
</table>

Furthermore, all teachers said that the parents of the involved students had positive attitudes. This is not a surprising finding, since their children were already participating in the activities. Nevertheless, it seems that the parents’ positive attitudes remain, even after the long period of engagement of their children with robotics (during holidays, after school hours, covering expenses).

In addition, most teachers (N=13) think that ER is crucial for the technological convergence of Greece with more technologically advanced countries. Teacher T8 replied:

T8: The most technologically advanced countries in the world have integrated their scientific advancements into the society, making life easier for citizens and increasing productivity. I believe that the best field to accomplish this is education. Hence, ER could have a huge impact on the country by achieving excellence in the field.
Finally, teachers were asked to provide their opinion regarding other robots like those that use open source software. The results (Table 7) were very interesting since most teachers would or have already used other robots based on open source (N=13). The most important factor seems to be economic (N=10 teachers), since such robots are cheaper than LEGO® Mindstorms®:

*T5: There is really no excuse not to use robots since it could be done with very little financial support with open source platforms.*  
*T11: I would use anything open source out of principle.*

One teacher said that both approaches have advantages and disadvantages and the main decisive factor is cost. Some teachers (N=4) believe that open source robots (e.g. Arduino) have better documentation and N=3 teachers believe that they have better growth potential. Despite all the positive comments towards the use of open source robots, some concerns were also raised. For example, teacher T3 responded:

*T3: I do not have the knowledge to support open source robots. I think that they require deeper programming knowledge and might not be appropriate for school students.*

In addition, the robotics Olympiad from WRO™ seems to be a powerful motive for 4 teachers. Teacher T2 made the following remark:

*T2: Open source robots are appropriate for class activities but not appropriate for competitions, since LEGO® are simple to use and good quality products.*

**Table 7.** Other robots: most commonly occurring themes.

<table>
<thead>
<tr>
<th>Open source robots</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive attitude</td>
<td>13</td>
</tr>
<tr>
<td>Financial issues</td>
<td>10</td>
</tr>
<tr>
<td>WRO™ competition</td>
<td>4</td>
</tr>
<tr>
<td>Better documentation</td>
<td>4</td>
</tr>
<tr>
<td>Faster growth</td>
<td>3</td>
</tr>
</tbody>
</table>

5.4. **Teachers: Additional Findings**

In order to examine if there is a place for ER in Greek educational system (RQ3), we gathered teachers’ responses. There were also various significant findings not directly related to the research questions of this study, but that nevertheless provided important information. Those findings come from additional questions that teachers answered regarding the national ER competition.

Firstly, we found some gender differences. More specifically, half of the teachers (N=9) mentioned that boys are more interested in robotics than girls (6 were neutral and only 3 disagreed).

Next, we asked about the funding resources of the teams. The educational robots are not provided by the Greek public schools and must be bought privately. As shown in table 8, seven instructors managed to get expenses covered from school budgets. Many asked the parents association to offer money (5 cases). Some stated that they found sponsorships from municipalities and private companies and they also involved students in fund raising activities (4 cases). However, in 6 cases students, teachers and the school’s principal covered the expenses from their private budgets.
Participants were also asked to explain difficulties they might have faced with their preparation for the national ER competition (Table 9). Six instructors said that they did not face any problems. Three instructors mentioned the financial problems they faced and four more talked about the timely efforts as main problems. Other problems mentioned were issues in coordinating the students, the nature of the task which was new to the students, lack of proper space and equipment and lack of information regarding the competition. We present here some of the teachers’ answers:

T6: The biggest problem we faced was the lack of money. The competition required more equipment than originally purchased.

T12: It was very difficult to find sponsors to cover the costs of the Robotics Olympiad. Until the last minute we did not know if we would be able to participate.

T14: Very difficult to coordinate groups. Time was an important issue, since most students had daily lessons outside schools, even during the summer months and their time was limited.

T17: Time was an issue for us. Children could not spend many hours for the preparation of the national competition. Some of them left due to time limitations, since they had to focus on the upcoming years’ national exams for university entry.

5.5. Students: ER Motivation and Skills acquired (RQ1)

During the preparations for the ER competition, students faced a number of problems, the most important being the programming demands. The lack of adequate programming knowledge was mentioned 9 times in the students’ answers (OEQ). In addition, some students found the time demands of ER, especially on their free time quite high, since this was mentioned 4 times. A few students (N=3) found the construction of the robot itself difficult.
Since the student data were mainly quantitative, a statistical analysis was also performed. However, due to the small sample, the results, although highly significant, can only show possible tendencies and require future in depth study. In particular, for this observational study and since all variables were categorical, a chi square test was performed. The significance level was set at .05 based on statistical guidelines\(^\text{12}\).

It seems that the competition itself became a good motivator for students. However, it was a strong motivator for some and not all. For example, students who already had good visual programming skills were more excited about their possible participation in the Olympiad, \(x^2 (4) = 11.818, p<.05\). The Olympiad functioned as an important motivator for people that stated that the ER activities were rather easy, \(x^2 (2) = 6.263, p<.05\). This phenomenon might occur because better students believed in their abilities and their possible participation in an Olympiad was regarded as a realistic goal. Similarly, the possible participation in the Olympiad was a strong motivator for students with an active interest in Computer Science, \(x^2 (4) = 12.424, p<.05\).

In the question investigating gender biases within the student population, asking whether boys are better than girls in such activities, motivated learners (motivated by the possible distinction to the Olympiad) did not report gender biases and seemed to believe that boys and girls can be equally good. However, not very motivated learners seem to report significantly higher gender biases, \(x^2 (4) = 9.818, p<.05\). In addition, we found that dedicated students (students that reported their willingness to participate in similar activities), reporting interest in similar future activities, do not report gender biases compared to less dedicated students, \(x^2 (4) = 10.769, p<.05\). The differences in gender biases between good and not so good students might be explained with the theory of locus of control [46], since good students usually have an internal locus of control (they feel solely responsible for their success or failure), whereas not very good students seem to have an external locus of control (the factors of their failure or success are external to them and in this case, gender can be viewed as a reason for failure/ success). This is a very interesting finding that is worth investigating further in studies focusing on gender differences in education.

5.6. Students: ER Learning STEM concepts (RQ2)

In the open-ended questions, students were given the opportunity to express what they liked and disliked in ER. Programming was mentioned 9 times as one of the best feature of ER. Students liked the fact that they could construct their own robots (mentioned 7 times), the learning that occurred during their engagement with ER (6 times) but also the competition itself (6 times). Students liked the competition because they enjoyed the atmosphere, the thrill, the travelling, and meeting new students. The fact that they had to collaborate with others, helped them find new friends with similar interests (mentioned 4 times). ER were also liked because of their creative nature (mentioned 3 times) and their entertainment value (mentioned 3 times).

Concurrently, 5 students mentioned that the competition was not a positive experience, since they identified problems with the organization of the competition and they felt unnecessary pressure. Interestingly, they mentioned that competing against private schools, with better equipment and better school facilities, was not fair. Coming from public schools they were often lacking equipment, had problems raising money to cover their travelling expenses and had to spend out of school time. Three students also mentioned that they did not enjoy the programming language used.

As also seen previously, most gender biases seem to be reported by students with lower programming skills. As the programming skills increase, the gender biases are reduced, $X^2 (4) = 13.429, p<.005$. Although some people seem to believe that girls are not as good as boys in ER activities, the findings of this study, showed exactly the opposite, since gender differences were found. From the girls participating, most reported high level of programming skills, whereas most of the boys participating reported low level of programming skills, $X^2 (2) = 6.389, p<.05$. In addition, all females participating found the activities easier, whereas only half of the boys participating found them easy. The other half of boys thought the activities were of medium difficulty, $X^2 (1) = 5, p<.05$. It was also found that although all boys thought that they learned basic engineering principles, not all girls would agree with them, since 1/3 of the participating girls had a neutral opinion about the issue, $X^2 (1) = 8.571, p<.005$. Finally, when asked whether boys are better than girls in such activities, all girls disagreed. However, it seems that most of the boys think that they are better than girls and gender biases exist, $X^2 (2) = 8.571, p<.05$. The above findings might reflect a rather traditional society in which gender biases still seem to exist. In that light, the finding that girls were indeed better than boys might be due to the fact that only girls who were already good at programming and had high self-esteem, registered to participate in the activities. This does not seem to be the case with boys, since boys of different programming skills participated.

Furthermore, students with higher overall school marks seem to have a higher interest in CS, compared to students with lower marks, $X^2 (2) = 12.033, p<.005$. Again, students with higher overall school marks reported a positive attitude towards future involvement with similar activities, compared to lower mark students, $X^2 (2) = 12.033, p<.005$. In addition, the better students also reported higher gains in learning in terms of problems solving, $X^2 (1) = 4.351, p<.05$ and programming learning, $X^2 (1) = 11.917, p=.001$. Therefore, it seems that not all students get the same learning benefits from ER and the better students seem to be benefited the most.

This finding is not only present with the overall school marks but it remains when students' existing programming skills are compared to factors like problem solving, $X^2 (2) = 5.962, p<.05$, cooperation $X^2 (2) = 11.250, p<.005$ and programming learning from ER, $X^2 (4) = 15.128, p<.005$. Thus, again it seems that better students have higher learning gains.

Yet again, students with existing good skills with visual programming languages, found the activities easy, $X^2 (2) = 17.037, p=0$, and reported higher learning benefits for problem solving, $X^2 (2) = 12.692, p<.005$ and overall programming learning, $X^2 (4) = 19.615, p=.001$. Problem solving abilities also increased for students that found the ER activities easy, $X^2 (1) = 6.923, p<.01$ and people with good previous knowledge in pseudo-language reported higher learning levels from ER in regards to programming, $X^2 (4) = 15.128, p<.005$ and engineering, $X^2 (2) = 13.929, p=.001$.

It seems that ER has certain rather high cognitive demands, and in line with the previous findings, better students have higher learning benefits. It also seems that older students are also more satisfied with ER, in terms of learning. For example, older students said that they were able to improve their programming skills, $X^2 (6) =15.128, p<.05$ and to have higher levels of self-discipline, $X^2 (6) = 17.963, p<.05$. Interestingly, junior high students did not enjoy the cooperation opportunities as much as the students from the other levels did (including younger and older). This could be possibly explained with the onset of adolescence and the awkwardness young teenagers might feel in working with others, $X^2 (3) = 10.556, p<.05$.

It is not surprising that students who perceived higher learning benefits from ER are the ones who also mention their intention to continue participating in similar future activities, $X^2 (2) = 14.024, p=.001$.

5.7. Students: ER Curricula and Attitudes (RQ3)
In investigating whether ER should be a part of the school curriculum, we gathered some very interesting data. For example, although older students report the highest learning benefits (section 5.6), it seems that they are the ones more reluctant than younger students to include ER in the school curriculum, \( x^2 (6) = 31.282, p = 0 \). This might be due to the fact that the Greek schooling system is heavily loaded with many different subjects and students might be afraid to add yet another one in their heavy daily schedule.

It was also found that students with lower programming skills were also reluctant to add ER in the school curriculum, probably for similar reasons, \( x^2 (4) = 15.128, p < .005 \). Moreover, students who did not enjoy cooperative activities are the ones who also do not wish to include ER in the school curriculum, \( x^2 (20) = 8.846, p < .05 \). This is not surprising, because ER demand cooperation in a school setting and this would force more shy or introverted students to cooperate with others.

Finally, it seems that the parents’ opinions on that matter are very important to students, since students who did not wish ER to be a part of the school curriculum also reported that their parents were not negative but reluctant, \( x^2 (2) = 30, p = 0 \). In the same way, students who were reluctant with cooperative activities also reported that their parents were reluctant with the introduction of ER in the school curriculum. These findings seem to reflect a more conservative attitude of the family towards alternative teaching approaches such as ER and cooperative learning.

5.8. Students: Additional Findings

Although not a part of the initial research questions, the following findings provide very useful insights. Among the most interesting was the relationship of the better students in terms of programming skills, the older students and the more motivated students with games \( x^2 (4) = 10, p < .05 \), \( x^2 (6) = 20.202, p < .005 \) and \( x^2 (4) = 10.413, p < .05 \), respectively. It seems that these types of students do not spend much time playing games. Traditionally, games are not considered an important part of education and in many cases a waste of students’ time. At least in Greece, games seem to be viewed as distraction elements rather than potential learning tools. In this light, it is not surprising that students with more knowledge and motivation either do not play as much as other students or at least they do not report playing, since this is what is expected from an older and/or good student. This finding seems to reflect the traditional state of the Greek educational environment.

6. Discussion

The first research question investigated teachers’ and students’ attitudes, concerning the students’ benefits from their involvement with ER in regards to skills and motivation. The results seem very promising. All teachers agreed that ER highly motivate students and boosts their will for learning. Teachers also noted that their students develop very important skills like problem solving, collaboration and creativity. Further analyzing some of the findings, it should be noted that the level of engagement with ER for all the participants (students and teachers) was very high, indicating personal involvement for purely voluntary activities. This could be due to the very nature of educational robotics that seem to excite the students, but it could be also due to the upcoming competition which also motivated students. It is also important to note that teachers did not have any financial benefits for their involvement with the ER and in many cases they also had to contribute on their own. The competition and ER seem to be a very strong motivator for students and especially for the ones with higher overall marks and programming skills. These are also the students who report the highest learning gains.

The second research question investigated whether ER could be used to teach basic STEM principles, like programming and engineering, at a school level. Most teachers believe that their students can learn STEM principles like programming and engineering with robotics. Although
robotics does not focus exclusive on programming, there seems to be the main learning outcome like a previous study has showed [47]. Teachers reported that ER enhances CT and could help learning from early ages. As far as engineering is concerned the findings were not so promising. This is not an unexpected finding considering the fact that only LEGO® Mindstorms® were involved in this study, which use readymade building blocks that students can assemble. The student data also showed that previous knowledge is very important and the better and/or older students were benefited the most. In line with constructivist principles, knowledge needs to be built on previous learning in order to be most effective [48]. Some students’ attitudes also reflected gender biases but these were only expressed by boys and by not top students. Although these are only students’ opinions, the present study found indeed gender differences but in the opposite directions and participating girls were all top students. It seems that girls of lower abilities are either hesitant, self-conscious or even unwilling to participate, unlike boys who try ER regardless of their personal programming and school abilities. Additionally, half of the teachers that participated in our study, believe that boys are more interested in ER than girls. This is a very interesting finding reflecting the structures of a traditional society that differentiates between gender appropriate activities. Nevertheless, it seems that teachers view robots as an opportunity to engage all students and increase interest in technology. They see a potential in educational robotics that should be explored further. However, the increased cost of robots in a setting with significant financial difficulties might discourage people from using them.

The third research question investigated attitudes regarding the introduction of ER in the school curriculum. As expected, the majority of the participants consider ER necessary. Although there are different opinions concerning the age of the children that should be involved in robotics, the need for strengthening technological knowledge seems to be recognized both by teachers and by students and parents. However, ER could be introduced in the compulsory curriculum under certain conditions. First, students’ computational reasoning skills should be enhanced prior to their engagement with ER. Second, the entire Greek school curriculum needs to allow for the introduction of alternative teaching methods and not simply add one, only increasing the workload of an already heavy program. Finally, it is interesting to note one teacher’s (T13) opinion, who believes that any possible learning benefits will be lost if there is no follow up of the activities and further continuation, including a connection to real industries. This is a very important comment, since there seems to be a need for altering the existing curriculum and possibly changing our pedagogical practices (connection to real life activities). This is definitely something missing in the current Greek educational system where learning activities seem to be disconnected from the outside world. ER could provide a good solution to bridge this gap.

6. Conclusions

The present work is an observational study consisted of two phases, recording teachers’ and students’ opinions regarding ER from a robotics competition. In the first qualitative phase data collected from 18 teachers and examined their views about their students. The results showed that: (a) with ER students increase their intrinsic motivation for learning within CSE, (b) students develop numerous skills, (c) students can learn basic programming principles in a fun and creative way and develop CT, and finally (d) teachers consider ER a necessary part of compulsory CSE. For the second phase, we designed a survey grounded in students’ attitudes towards ER through multiple choice questions and 30 responses were collected and analyzed. The results from the second phase demonstrated that robotic activities provide the necessary means for increasing intrinsic motivation through students’ eyes too. There also seem to be numerous learning benefits for students, since apart from gaining programming knowledge, they also seem to increase their collaboration, problems solving and creativity skills as well.
The study has several implications for practice and policy. The results of this study verified that ER can be an important and influential factor in determining students’ intention to participate in activities that develop their skills and promote their learning. Scholars, educators and practitioners should focus on such activities because their predictive effect on children’s adoption is high. Past research [23] has also shown that strategies such as ER provide an immediate technical service are an effective means of motivation and learning. Curriculum designers and practitioners should strive to increase participants’ intrinsic motivations and provide alternative environments for learning such as robotics.

In addition, our findings imply that teachers and students in Greek education are ready for alternative teaching methods in CS, and robotics might be a good addition to the present curriculum. The fact that most of them mentioned novelty, challenge and collaboration can be considered as a requirement for curriculum designers. However, certain aspects regarding alternative teaching methods also emerged, implying that simply adding yet another school subject, such as robotics is not the way forward. The entire school curriculum needs restructuring in order to accommodate such activities and build on students’ previous knowledge and skills.

Although findings provide meaningful outcomes for the application and theory of ER in CSE, understanding both teachers’ and students’ perspective, this study has some design and methodology characteristics that may influence the interpretation of our findings. Due to the substantial differences of preconditions, circumstances and influence factors, it is difficult to transfer this research results to a more international context. For this purpose, section 3.2 provides a brief analysis of the Darmstadt model reflecting all factors that might be relevant for Greek CSE. Moreover, as in all empirical studies, the sample of the participants may have contingent effect on the results. With a broader sample size, evidence to further support our conclusions could be given and allow the results to be further generalized beyond the scope of this study. However the use of a mixed method approach and the fact that the results were quite homogeneous, allows us to reduce this effect. Nevertheless, the findings showing a very high level of engagement and motivation of both teachers and students and are still widely applicable as they show certain tendencies that are worth studying further at worldwide level.

Future work may focus on different issues of alternative CS methods like ER. We will attempt to record attitudes of different stakeholders like policy makers and parents. We also aim to examine the impacts of the ER competition among a broader group of participants including other countries from the World Robot Olympiad.

As education moves forward, it is important to document teachers’ and students’ motivations and experiences and to build a broader base of evidence for their perceptions regarding learning. To that end, this study builds on a wider longitudinal effort to better control questions on motivation and learning in CSE.

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