Participants' perceptions about their learning with FIRST LEGO® League Competition – a gender study

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Abstract. Robotics Competitions as FIRST LEGO® League (FLL) Competition are gaining more and more popularity, however, what are the participants learning? The present study investigates participants' perceptions regarding their learning with FLL Competition. In particular, it explores participants' perceptions about their learning about the world, learning to solve problems, learning to engage, learning to apply knowledge, learning to communicate, learning to apply the technology cycle, studies participants' perceptions on the competition activities, but, more importantly, it explores gender differences in students' perceptions about their learning in the competition. A quantitative methodology is used, a questionnaire collecting data on participants' perceptions was first validated by a team of experts and then completed by 84 participants of the Finals of FLL Competition 2018 in Greece. Results show that participants' perceptions on their learning are very positive: a) they report that they enjoy taking part in the competition as they are engaged in activities of their preference, b) participants consider the competition as a great opportunity for learning about real word problems and for the acquisition of skills in STEM areas of studies, c) participants view that they acquire social, collaborative and communication skills and d) regarding gender, females tend to be more engaged, enthusiastic, creative, eager to experiment and more likely to adopt collaborative strategies than males.

Keywords: Educational Robotics, FIRST® LEGO® League competition, gender studies.

1. Introduction

There is a growing interest in studies and professional careers related to STEM disciplines (Science Technology, Engineering and Mathematics) internationally. The total number of STEM graduates increased from around 755,000 in 2007 to 910,000 in 2012 in the EU countries, corresponding to an average annual 3.8% growth rate and an overall 20% increase over the period [1]. Similarly, over this period, the percentage of tertiary STEM graduates in Greece has increased around 4% [1]. However, despite the numerous gender specific actions taken by the European Commission and the local governments, female participation rates in STEM studies are considerably lower than male participation in the disciplines of computing and engineering [1]. STEM labor market is expanding and so needs to expand female presence in the fields of computing and engineering. Main objective of the European Commission is to achieve a better gender balance in STEM studies [2]. A wider female involvement in computing and engineering studies would encourage their future employability.

Student learning and acquisition of skills in the areas of computing, engineering and STEM disciplines in general can be facilitated through classroom use of Educational Robotics (ER). Research in the field has proven that Educational Robotics (ER) can effectively be used to equip students with skills in the area of STEM education [3] [4] and promote students' interests in STEM subjects [5]. ER is a teaching tool that engages both male and female students and encourages their affinity to STEM disciplines. ER offers immense opportunities for teaching and learning; due to its cross-curricular nature, it can be implemented in a variety of disciplines [6] [7] [4]. Students through ER project-based activities can work on real-world problems and challenges [8]. Educational robotics is an engaging learning tool that through hands-on activities makes learning fun and motivates students in learning [8]. Regarding gender, ER is attractive to both girls and boys, however, activities engaging to both males and females need to be designed [3] in particular, activities that maintain females' interest in robotics during their teens. Robotics competitions may promote both genders' learning and acquisition of STEM skills and this will be further explained in the section below.

2. Theoretical Background

2.1. Educational Robotics competitions´ impact on students´ learning

Educational robotics is not integrated into the school curriculum - most of the times, robotics activities are extracurricular [9]. ER activities often take place in informal educational contexts after-school clubs or summer camps that often lead to the participation in a competition. Educational robotics competitions provide a unique and vital learning opportunity for school age children [5]. Significant are the learning outcomes that participants reap of ER competitions in the area of STEM. In robotics competitions children independently identify and understand principles, concepts, and elements of practice that are fundamental to programming and engineering [10]. In addition, through robotics competitions students better understand principles and concepts that they had previously found challenging while trying to make the robot function [10].

Student participation in ER competitions brings additional benefits beyond the understanding of STEM principles and concepts. For example, it brings an increased student interest and motivation to take additional STEM courses in their studies [11]. Participants display a more positive attitude toward science and science related areas [12]. Robotics competitions have proven to be very motivating for children [10] [13]. Students' intrinsic and extrinsic motivation, self-determination and self-efficacy concerning robotics are maintained at a high level throughout robotics competitions [4]. As a result, participating in competitions is a motivating ER activity that positively affects students´ affinity to STEM disciplines.

In this particular study, students´ perceptions on their learning within competitions will be examined in the context of FIRST® LEGO® League (FLL) competition. FLL competition is an international robotics and research competition operated by the non-profit organization For Inspiration and Recognition of Science and Technology (FIRST) and involves students from 9 to 16 years old [14]. Each year a new themed challenge is released and the teams research, design, and present results of their work to the community and panels of judges [14]. During students' preparation for the competition and in the competition itself, the participants have gains in a variety of fields. First of all, students show high and positive attitudes and motivation towards ER both before and after the competition [4]. In addition, students develop a greater appreciation for and a more positive attitude regarding the importance of science and the social implications of science-related issues [15]. The competition also sharpens students' problem-solving skills as problem-solving is embedded in all parts of the competition- robot design, robot game, project and core values [16]. Through the competition, participants' confidence in their problem-solving skills is boosted [17]. More detailed, participants improve technological problem-solving styles, problem clarification, developing a design, evaluating a design solution, and overall technological problem-solving performance [17]. To sum up, according to the above-mentioned authors, robotics competitions offer considerable learning outcomes, however, are they popular with both boys and girls?

2.2. Gender differences observed in educational robotics competitions

ER competitions do not seem to attract as many female participants as males. In particular, in a research carried out in the context of FIRST® LEGO® League competition in 2009, "the large majority of FLL participants were boys (approximately 70%) with the average team consisting of five and six boys and two to three girls" [18]. Despite the fact that both male and female participants' learning was positively influenced by their participation in the competition, a divergence was observed regarding their interests and self-perceived skills gained [18]. On the one hand, males were more likely to show interest in computers and technology and technology-related careers and report gains on skills in these fields [18]. On the other hand, females tended to show more interest in projects and in going to college and report gains on social skills and communications rather than on technology-related skills [18]. Females tend to display lower self-efficacy in robotics than males, despite the fact that they are as competent as males are [19].

To tackle female lower self-efficacy in educational robotics, it is suggested that females practice building and programming through hands-on activities [19]. The Roberta Initiative was also launched proposing themes and experiments that are more interesting for girls but do not exclude boys, aiming at increasing females' self-efficacy in educational robotics [20]. In a recent research, it has been observed that as females grow older, they are less involved in programming, meaning that their programming interest decreases as the years go by [21]. It is suggested that girls get involved in informal computing experiences to maintain their interest in pursuing STEM-related careers [21]. Interestingly, it was also observed that females showed more positive attitudes and motivation for learning robotics after their participation in FLL competition [4]. Apart from their attitudes and motivation, female students' self-efficacy was boosted as "their attitudes and motivation increased to the point that they felt that they were better than male students" [4]. All in all, noticeable is the positive impact of the competition on females' attitudes, motivation and self-efficacy regarding ER and STEM.

3. Methodology

Objective of this research project is to look into the participants' self-perceived learning within the competition and to further examine whether there are significant gender differences in the participants' perceptions regarding their learning with the competition. The variables of our study are students' learning about the world, learning to solve problems, learning to engage, learning to apply knowledge, learning to communicate, learning to apply the technology cycle and their opinions about the FLL competition. For the purpose of this study, an instrument measuring participants' self-perceived learning was validated by a team of experts.

3.1. Research questions

- What are the participants' perceptions about their learning in FLL Competition?
- To what extent do females' perceptions about FLL Competition differ compared to males'?

3.2. Context and Sample

The sampling was conducted with self-selected students among the participants of the Final Competition of FLL in Greece held in March 2018 themed "Hydrodynamics". A total of 84 participants took part into the research. The sample consists of 45 males and 39 females representing a 54% and 46% of the sample respectively. The average age of the participants was 13.05, (SD=1.58) while the age range varied between 10 and 16 years old. A significant majority of the participants (64% of the total sample) is between the age of 13 and 15 years old, while 33% of the participants is younger - between the age of 10 and 12 years old- and only a 3% of the total sample is over 15 years old. The participants completed the questionnaire on the second day of the competition right before the closing ceremony when all FLL challenges had been completed.

3.3. Research Instruments

The questionnaire distributed to the participants of the Final Competition of FIRST LEGO® League (FLL) is the translation into Greek of Chalmers' questionnaire used in the Australian Regional FLL Competition [22].

Questionnaire content.
The questionnaire focused on students' self-appraisal of their learning and they were asked to respond to statements about: learning about the world, learning to solve problems, learning to engage, learning to apply knowledge, learning to communicate, learning to apply the technology/engineering cycle, and specific questions relating to the FLL activities [22]. Precisely, regarding the content of the questionnaire, there are 4 items collecting demographic data (participants' gender/age/team) and the main body of the questionnaire includes 36 Likert scale statements ranging from Almost Always to Almost Never and 7 open-ended questions. The items are categorized into seven dimensions: 9 items about learning about the world, 7 about learning to solve problems, 6 about learning to engage, 4 about learning to apply knowledge, 5 about learning to communicate, 6 about learning to apply the technology cycle, 6 about the participants' opinions and together with the 4 demographic items, the total number of the questionnaire items rises to 48.

Questionnaire Validation.
As a part of our research, the questionnaire was translated into Greek and validated by 15 experts at the field of educational technology and FLL Competition (7 males and 8 females), 8 of the experts were members of the judging committee in the FLL Competition 2018, while 7 of the experts were members of eduACT, the non-profit organization in charge of organizing FLL Competitions in Greece [23]. The experts validated the questionnaire and evaluated its items in terms of ambiguity, pertinence and importance by completing an online questionnaire on google forms[1].

First of all, experts' evaluation in terms of ambiguity will be presented. Based on the analysis of experts' answers, the questionnaire items were thought to be clear enough and easily understood by the children with the exception of the following four items. However, none of them reached an ambiguity rate higher than 50%. In particular, Q10 - 'I got a better understanding of the world outside of school' and Q11 - 'I learnt interesting things about the world outside of school' were considered to be ambiguous by 46% and 40% of the experts respectively. According to the feedback provided by the experts, Q10 was viewed as too obscure and misleading to the students. As far as item Q11 is concerned, the experts reported that the statement included the word 'things' and for this reason the item was considered to be unclear in the given context. Regarding Q25 - 'I was always engaged', 47% of the experts pointed out the ambiguity of the item as they considered the word 'engaged' semantically difficult to the students. Last but not least, Q39 - 'I was able to check my work' was considered ambiguous by 40% of the experts who underlined that the difference of this item when compared to the following item Q40 - 'I was able to think about my work' is not clear enough and stated that a further explanation is required. The rest of the questionnaire items were considered unambiguous by the great majority of the experts and received positive feedback.

Furthermore, experts evaluated the questionnaire items regarding their pertinence to the research objectives on a scale from 1 to 4. The questionnaire items were considered to be pertinent to the research objectives as 87.5% of the items received a score of 3.5

[1] The online questionnaire in Greek is available at https://goo.gl/forms/AvU6nAA1fBhhSE3g1

or higher. Interestingly, only item Q25 - ‘I was always engaged’ received a low score (2.4) and was considered by the experts to be the least pertinent to the research.

Finally, the experts evaluated the items regarding their importance to the research objectives on a scale from 1 to 4. All items were thought to be important to the research objectives as 77% of them were evaluated with 3.5 or higher. Items Q1, Q22 and Q25 received lower scores equivalent to 3.0 or less. More precisely, Q1 - ‘Which is your team?’ received a mean score of 3.0 and this implies that it was not considered very important to the research objectives by the experts. Q22 - ‘I did hands-on activities’ also achieved 3.0 and the experts pointed out that an example of hands-on activities should have been provided to make the question more explicit. As in the previous sections, Q25 ‘I was always engaged’ received a low score around 2.5 implying that this item was not very important according to the research objectives.

After expert validation, Cronbach's alpha test was run in order to measure the internal consistency or reliability of the validation questionnaire [24]. For the purpose of this research, the Cronbach's alpha test was once run for items of the validation questionnaire altogether and then it was run again separately per questionnaire part (ambiguity, pertinence, importance). The Cronbach Alpha for the total number of items of this questionnaire was 0.95 suggesting a high internal consistency. Regarding each scale, Ambiguity (α=0.81), Pertinence and Importance, (α=0.94) for both and this shows a high internal consistency of each scale.

3.4. Results and Discussion

The results of the research project will be analyzed per research question.

Research Question 1: What are the participants perceptions about their learning in FLL Competition?

Participants in the FIRST LEGO® League (FLL) competition provided positive feedback. When analyzing the questionnaire answers on a five-point scale, the means per section (see Figure 1) show that participants view their participation in the FLL competition as a very enriching experience as they learn about the world, they learn how to solve problems, to apply knowledge, to engage, to communicate and apply the technology cycle. Remarkable is the students’ evaluation of FLL Competition activities achieving a mean rate around 4,6 out of 5 (see Figure 1- section 7). Our findings indicate that competition activities are considered interesting, enjoyable, fun, challenging and well designed by most of the participants. Our findings are in line with previous research in the field [22].

Fig. 1. - Students' perceptions per section

More than 1/3 of the items are rated between 4.5 and 4.87 out of 5.0 (see Table 1), meaning that participants report that these practices were taking place very often or almost always in the competition. Furthermore, 58.3% of the statements were marked with a rate ranging from 4.0-4.49 out of 5.0, underlining that these practices were taking place often or very often. A limited amount of statements (4 out of 36) received a frequency rate ranging from 3.5-3.99. The limited number of items that received a less high evaluation, confirms that FLL participants view the competition as a very appealing and fruitful experience.

Table 1. Students' perceptions per item and gender - Means and Standard Deviation

Item	M(SD)			Item	M(SD)			Item	M(SD)		
	Males	Females	Total		Males	Females	Total		Males	Females	Total
Q1	4.36(.61)	4.62(.63)	4.49(.63)	Q13	4.39(.72)	4.41(.75)	4.40(.73)	Q25	4.26(.72)	4.68(.58)	4.47(.69)
Q2	4.43(.82)	4.56(.60)	4.49(.72)	Q14	4.22(.88)	4.36(.74)	4.29(.81)	Q26	4.31(.78)	4.49(.65)	4.39(.72)
Q3	4.34(.83)	4.56(.68)	4.45(.77)	Q15	4.52(.70)	4.65(.59)	4.58(.65)	Q27	4.44(.85)	4.51(.82)	4.48(.83)
Q4	4.09(.91)	4.28(.76)	4.18(.84)	Q16	4.26(.85)	4.24(.98)	4.25(.91)	Q28	4.20(.99)	4.05(.86)	4.13(.93)
Q5	4.40(.80)	4.38(.85)	4.39(.82)	Q17	4.24(.85)	4.62(.72)	4.43(.81)	Q29	4.60(.54)	4.72(.56)	4.66(.55)
Q6	4.18(.82)	4.44(.75)	4.31(.79)	Q18	4.55(.59)	4.59(.60)	4.57(.59)	Q30	4.35(.65)	4.56(.55)	4.45(.61)
Q7	4.55(.70)	4.67(.70)	4.61(.70)	Q19	3.76(.95)	3.97(1.01)	3.86(1.03)	Q31	4.30(.83)	4.33(.74)	4.32(.78)
Q8	4.34(.75)	4.62(.54)	4.48(.67)	Q20	3.98(.99)	3.81(.90)	3.90(.95)	Q32	4.81(.67)	4.79(.50)	4.80(.58)
Q9	4.36(.69)	4.49(.60)	4.42(.65)	Q21	3.93(.92)	3.76(1.01)	3.85(.96)	Q33	4.86(.47)	4.87(.34)	4.87(.41)
Q10	3.89(1.0)	4.23(.78)	4.06(.92)	Q22	4.16(.97)	4.24(1.00)	4.20(.96)	Q34	4.84(.43)	4.92(.35)	4.88(.40)
Q11	4.45(.77)	4.72(.56)	4.58(.68)	Q23	4.67(.65)	4.81(.57)	4.74(.61)	Q35	3.81(1.22)	4.05(.98)	3.93(.99)
Q12	4.73(.54)	4.77(.62)	4.75(.58)	Q24	4.29(.74)	4.27(.99)	4.28(.86)	Q36	4.45(.85)	4.64(.59)	4.54(.74)

The analysis of the students' perceptions leads us to summarize our findings:

- Participants report that they enjoy the competition as they are engaged in activities of their preference.

Remarkable are the high mean frequencies in Q33 “FLL activities were enjoyable” (M=4.87) and Q34 “FLL activities were fun” (M=4.88), together with low standard deviation (SD=.41) and (SD=.40) respectively, highlighting that the activities were enjoyable and fun almost always for everyone (see figure 1). In addition, students consider interesting the activities held in FLL Competition as they rated the item Q32 - “FLL activities were interesting” on average with 4.8 (SD=.58). Our findings are line with the fact that educational robotics is an efficient learning tool that helps to create a fun and engaging learning environment and keeps students interested and engaged in learning [8].

- Participants view the FLL Competition as a great opportunity for learning.

Students consider FLL competition as a great opportunity for learning about the world outside of school (Q1-Q8), implying a relation between competition with real word problems and STEM areas of studies. Results from previous research report that students who participated in robotics competition had a more positive attitude towards science and science related areas [12]. Additionally, in our research findings it was observed that participants clearly see the impact of the FLL activities on their ability to solve problems (Q9-Q13). The fact that FLL Competition cultivates students’ problem-solving skills was also observed in [16]. From our findings it is inferred that participants have the chance to develop their Computational thinking skills and more specifically they practice and acquire skills in the area of “Computational Problem-Solving Practices” [25]. Interestingly, Q12 “I learnt that there can be more than one solution to a problem” was impressively highly rated (M=4.75) (SD=.58) implying that through the competition the computational thinking practice “Using Computational Models to Find and Test Solutions” is developed [25]. Similarly, Q18 “I was finding new ways to improve what I was doing” could be linked to “Assessing Different Approaches/Solutions to a Problem” computational thinking practice (Kotsopoulos, 2017). Quite high is the mean in Q22 - “I was able to apply my knowledge in technology to solve problems” (M=4.2) implying that participants apply previously acquired practical knowledge in the competition often or almost always. Our findings are line with previous studies that reported that Educational robotics offers opportunities for hands-on and project-based activities that are closely connected to real-world problems and challenges [8].

- Participants view the FLL Competition as a great opportunity for collaboration and socialization.

Students’ answers in Q23-Q26, Q10 and Q14, show that FLL is a rich context for collaboration and socialization. Most students agree that they had the chance to get in touch with other students (Q23 - M=4.74). Regarding collaboration, in Q10 “I learnt how others solved problems” and Q14 “I showed others how I solve problems”, the mean of the students’ answers indicate that these behaviors were adopted often or very often and this confirms that FLL Competition is a great opportunity for collaborative learning. The results of our study verify the view that FLL Competition helps to increase participants’ social skills [18] and confirm previous research results according to which students after participating to the competition, felt that they had learnt how to work as part of a team and how to communicate effectively [26].

Research Question 2: To what extent do females' perceptions about FLL Competition differ compared to males'?

Aim of the research is to study any potential differences between males' and females' perceptions about their learning with FLL Competition: the two groups' answers will be compared and contrasted separately per questionnaire section. From a quick look at table 1, groups' means -between male and female students do not differ substantially, however, there is a tendency that female students demonstrate slightly more positive perceptions in the questionnaire than males. More positive attitudes of female participants after the FLL Competition were also observed in previous research [4]. However, it needs to be pointed out that the participants joined the competition voluntarily - females participating in the competition might not exemplify average females as they may be more confident with STEM subjects than other females. Males' and females' perceptions will be analyzed below per questionnaire section.

- Section 1- Learning about the world

In all questionnaire items in this section except for item Q5, females' perceptions on learning about the world are slightly better than the ones of males, however their differences are not significant. Females seem to be slightly more aware of the connection of the FLL Competition challenges to the real world and everyday problems. Informal STEM activities that are structured around real-world problems and providing help to others, are attractive to girls [27]. In FLL Competition female participants seem to be more enthusiastic about the learning outcomes of the competition, its usefulness and connection to the real world.

- Section 2- Learning to solve problems

In section two, non-significant differences were reported regarding participants' perceptions: females tended to provide more positive feedback regarding their learning to solve problems than males. However, in previous research it was observed that female FLL students perceived their overall technological problem-solving style no differently than males [17]. Females more often report that they are eager to learn from others e.g. Q10- "I learnt how others solve problems" when compared to males. This could imply that females would better collaborate than males. Furthermore, females provide slightly better feedback regarding testing new and different approaches to find a solution (Q11- "I experimented new ways to solve problems") and this could also imply that females tend to be more creative than males in the context of the competition.

- Section 3 - Learning to engage

Females perceive their learning to engage slightly higher than males, however, the differences are not significant with the exception of item Q17 "I was trying new ideas".

The T-test did not reveal statistically important differences, however, the Pearson correlation test, showed a significant positive correlation between gender and Q17 (r= 0,238, p=0.35). Based on these findings, it could be inferred that when females learn within the context of the FLL, they seem to be more engaged, enthusiastic, creative and eager to experiment with new approaches than males. These findings are in line with [26], in which it was observed that females seemed to have a more positive learning experience within the FLL Competition than males and considered it more rewarding.

- Section 4- Learning to apply knowledge

In this section, non-significant gender differences were reported. Females perceived their learning to apply knowledge in science and mathematics within the competition slightly lower than males while higher in technology. These findings may suggest a higher self-efficacy in technology in females after the competition also noted in [4].

- Section 5 - Learning to communicate

As far as the questionnaire section "learning to communicate" is concerned, females provided higher rated feedback compared to males. Significant gender differences were observed in Q25 – "I asked other students to explain their ideas". The T-test carried out did not reveal statistically important differences, however, the Pearson test, showed a significant positive correlation between gender and Q25 (r=0,305, p=0,006). These results show that it is more common for females than males to learn by asking other students to explain their ideas in the context of the FFL. It has been previously observed that FLL helps increasing participants' social skills [18], collaborative and communication skills [26]. Research findings suggest that in our context females adopt collaborative strategies more often than male participants. It is more common for females to acquire knowledge by interacting with others while giving and receiving advice.

- Section 6 – Learning to apply the technology cycle

In this section, non-significant gender differences were reported. Females perceived their learning to apply the technology cycle in the FLL Competition slightly higher than males in all related items apart from Q28. These findings are in line with [4], suggesting females' higher self-efficacy in technology in this competition. Items in this section related with the ability to investigate, design, create and reflect on tasks are closely connected to computational thinking practices as defined by Weintrop [25]. Females seem to perceive their acquisition of computational skills higher than males, although differences are not significant.

- Section 7 - Opinions

FLL Competition activities receive positive feedback from both males and females. Given the almost equally rated first three items of the section (Q32, Q33, Q34), the FLL activities seem equally interesting, enjoyable and fun for both males and females.

3.5. Conclusions

The present study consisted of the expert validation of a questionnaire on participants' learning within FLL Competition and the analysis of participants' perceptions. Data was collected from 84 participants of the FLL Finals in Greece. Results showed that: a) FLL Competition participants report to enjoy taking part in the competition as they are engaged in activities of their preference, b) participants consider the competition as a great opportunity for learning about real word problems and acquiring skills in STEM areas, and c) participants view that they develop their social, collaborative and communication skills in the competition. Regarding gender, results show a generalized but not statistically significant tendency of female participants to perceive their learning more positively than males. Based on statistically significant results, females in the context of FLL Competition seem to be more engaged, enthusiastic, creative, eager to experiment and more likely to adopt collaborative strategies than male participants. Finally, given these findings, future research is needed to study greater samples and to draw a comparison between self-perceived learning/ self-efficacy and gender in informal robotics activities. It is also recommended to study the actual process of learning with FLL through observation, following a qualitative approach. The relation between self-perceived learning and actual learning could additionally be explored in future research.

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