Problem-solving at the Azorean Robotics Open: A study of the First Challenger competition

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Abstract

This paper reports on a study of the students' participation in the First Challenger competition, held in the Azorean Robotics Open (ARO), to understand how the First Challenger competition promotes interpersonal relationships and fosters critical thinking and problem-solving activity. The First Challenger competition explores basic robotics behaviour concepts, such as following a line and detecting colours, which implies testing and gauging the sensors and programming the robot. In ARO, the teams receive a robotic kit. It is part of the competition to assemble the robot. The teams were mostly students from basic school, between 12 - 16 years old, and some had previous experience in robotics because of their activities in school robotics clubs. Data collected showed that the robot assembly was identified as simple, but not the process of programming optimisation, highlighting the relevance of previous knowledge in programming and robotics to the competition's success. Regarding collaboration and sharing, most participants strongly collaborated within their own team, as expected. In the end, participants recognised that their teamwork skills were improved. Cooperation among participants from different teams also occurred, although to a lesser extent, suggesting the competitive nature of the challenge avoids this kind of interaction.

Keywords: Problem-solving · First Challenger · Azoresbot · Robotics.

Título: Resolução de problemas no Open Açoriano de Robótica: Um estudo da competição First Challenger

Resumo: Apresenta-se um estudo sobre a participação dos alunos na competição First Challenger, realizada no Festival de Robótica dos Açores (FRA), para compreender como a competição First Challenger promove as relações interpessoais e fomenta o pensamento crítico e a resolução de problemas. A competição First Challenger explora conceitos básicos de comportamento robótico, como seguir uma linha e detetar cores, o que implica testar e aferir os sensores e programar o robô. No FRA, as equipas recebem um kit robótico. Faz parte da competição a montagem do robô. As equipas eram maioritariamente constituídas por alunos do ensino básico, com idades compreendidas entre os 12 e os 16 anos, alguns com experiência prévia em robótica devido às suas actividades em clubes de robótica da escola. Os dados recolhidos mostraram que a montagem do robô foi identificada como simples, mas não o processo de otimização da programação, o que realça a importância dos conhecimentos prévios em programação e robótica para o sucesso da competição. Em relação à colaboração e partilha, a maioria dos participantes colaborou fortemente dentro da sua própria equipa, como esperado. No final, os participantes reconheceram que as suas competências de trabalho em equipa foram melhoradas. A cooperação entre participantes de equipas diferentes também ocorreu, embora em menor grau, sugerindo que a natureza competitiva do desafio evita este tipo de interação.

Keywords: Resolução de problemas · First Challenger · Azoresbot · Robótica.

1 Introduction

Technology has evolved exponentially and is "an unavoidable tool of the modern world" [24]. Robotics have been playing an increasingly present role in people's daily lives, and it is applicable in numerous areas, namely in industry, services and commerce, education and defence. In education, it can have a considerably powerful impact on the teaching-learning process in Science, Technology, Engineering, Art and Mathematics subjects (STEAM). Lima and Almeida [12] consider the "potential for multi-disciplinary research and international interest" in robotic activities. Robotic kits have become tools for the efficient and fast integration of students. In schools, there is a need for technological transformations and a demand for more timely responses [13] [14] [24]. As explained by Papert [4] "this obviously implies that schools as we know them today will have no place in the future. But it is an open question whether they will adapt by transforming themselves into something new or wither away and be replaced" (p.9).

Moreover, by using robotics, students can learn by doing, following a hands-on approach [21]. This perspective is based on the theoretical principle of constructionism, referred by Papert [4] as "the opportunities offered by technology to base education for science and mathematics on activities in which students work towards the construction of an intelligible entity rather than on the acquisition of knowledge and facts without a context in which they can be immediately used and understood". Through its exploration, students also develop knowledge and explore concepts in an interdisciplinary perspective (e.g. STEAMS) and an effective way to apply this concept is through the development of projects in the teaching-learning process [14] (p.127).

Still, with robotic projects, students engage in activities that promote cognitive development, social skills and creativity [1], *i.e.* "problem-solving-based learning or project-based learning" [5].

This paper reports on a survey study into students' participation in the First Challenger competition, held in the Azorean Robotics Open (ARO), Azores, Portugal, to understand how the First Challenger competition promotes interpersonal relationships and fosters critical thinking and problem-solving activities.

The First Challenger competition is a usual competition in the Portuguese Open Robotics [26] [27] and explores basic robotics behaviour concepts, such as following a line and detecting colours. In ARO, the teams receive an Arduino robotic kit, dubbed AZORESBOT, and they have to assemble and test the robot before the competition starts[1]. The report was made to a total of 27 participants, aged between 13 and 15 years old. The majority of participants had previous experience in programming and robotics activities in their school robotic clubs. In the following section, we will present the First Challenger competition and describe the robotic kit used. Then, the results of the inquiry are discussed. Finally, the conclusions are presented.

2 First Challenger in the AOR

The first AOR was organised in 2019 in Ponta Delgada. This event included three different challengers such as First Challenger, Tell a Story and Freebots, similar to previous competitions organised for the Portuguese Open Robotics [28] in the mainland. The First Challenger has the same rules provided by the Portuguese Open Robotics, with the same three challenges: i) Follow a line; ii) Follow a line and detect colours and iii) Follow a line, detecting colours and going through a tunnel[2]. But, in the AOR, participants assemble the robot AZORESBOT (see Figure 1) before the competition starts. This strategy was adopted because schools in the Azores had almost no previous contact with educational robotics, fostering teams without a robot to participate in the event.

Since then, in the following editions (*i.e.* 2022), First Challenger have been always present.

Figure 1. Azoresbot robot (In Cascalho *et al.*, [7] p. 6)

[1] Teams were composed of three students and a tutor (professor or older student) who could help students in the assembly and the programming.

[2] Inside the tunnel, the robot will not have the line to follow and must use the ultrasonic sensors

The robot AZORESBOT [8] is an Arduino robot with ultrasonic, line follower and colour sensors, the motors and the RGB LED to signal a detected colour as depicted in table 1. It is suitable to the First Challenger, having the necessary sensors to all the levels of the challenge.

Table 1. List of the components used in the AZORESBOT robot (in [8])

Component	**Reference**
Micro-controller	Arduino Mega 2560
Motor driver	L298N
Motor	Micro motor DC 140 rpm
Ultrasonic sensor	HC-SR04
Colour sensor	TC3200-WS
Line follower	TCRT5000
Led	LED RGB
Battery	Li-ion 18650

Teams assemble the robot from a kit provided by the organisation and test it. Organisers also provide some simple code examples for each team to test the different sensors and actuators. Small meetings with all team members provide discussions about programming and some help in the interaction with the Arduino platform. The final code must be provided to the juries of the competition [7] [8] [9].

3 Results assessment

The survey in this study addresses the participation in the First Challenger competition in AOR 2022, designed to answer the general question "Does the First Challenger competition promote the development of interpersonal relationships, critical thinking and problem-solving?". Three more specific questions (or sub-questions) were addressed:

- In a competitive context, do students collaborate and share within the team group?
- Throughout the activities, do students come up with ideas and solutions to solve the challenges?
- Did students interpret the available information to make decisions in order to solve the challenges?

The questionnaire was designed for two distinct phases. At the beginning of the First Challenger preparation, an initial questionnaire was applied to characterise the participating students and identify their reasons for participating. Then, after the end of the competition, a second questionnaire was applied to collect data on the topics mentioned above.

The competition was attended by nine teams, with a total of 27 participants. In the first questionnaire, all participants gave their consent and answered the questions. Thus, 22 males' gender (85%), 1 female gender (4%) and 4 other genders (15%) participated in the First Challenger. The majority were between 13 and 15 years old (33%) Table 2 presents the distribution of participants' age.

Table 2. Distribution of participants according to age range.

10 - 12	13 - 15	16 - 18	> 18	total
n | %	n | %	n | %	n | %	n | %
5 | 19	9 | 33	7 | 26	6 | 22	27 | 100

(Note: Each column shows the number and percentage of participants)

When filling in the questionnaire we used an alphanumeric code on respondents' badges to ensure their anonymity. Each code was composed of a number and a letter, the number corresponding to the team and the letter to the participant.

The initial questionnaire was applied to students on the first day of the event. After the reception and the first explanations about the procedures of each competition, one of the researchers went to each team to request the completion of the online questionnaire, using a QR code. The final questionnaire was applied on the last day of the event, after the end of the competition activities. Of the twenty-eight initial responses, twenty participants responded, with two respondents removed for lack of consent. To evaluate the intensity levels of the participants' opinions, a Likert scale was applied: 1 - totally disagree; 2 - partially disagree; 3 - indifferent; 4 - partially agree; 5 - totally agree.

4 Results and Discussion

The results were organised to answer the research questions presented in section 3. Let's first characterise the sample of participants in the First Challenger.

Regarding the previous knowledge of the participants, 23 of them (85%) reported having previous programming knowledge and 24 participants (89%) reported having robotics knowledge. This knowledge was mostly obtained in the programming/robotics clubs and in the Information and Communication Technologies (ICT) subject, as shown in Figure 2. The importance of clubs for students' acquisition of knowledge in programming and robotics is clear, not least because 23 participants mentioned the existence of a club in their schools (85.2%). As for the preference for the areas of technologies, programming and/or robotics, 26 participants (96.3%) reported liking these areas.

Regarding teamwork, most participants (85%) stated that they enjoy working in a team, 21 participants (78%) had good knowledge of the First Challenger rules, and 20 participants (74%) had never participated in any robotics-related event. Regarding motivation, 24 participants (89%), reported being motivated to participate in the competition and they considered it as an opportunity to learn new concepts, apply knowledge, enjoyment and curiosity for the areas of programming and/or robotics: "Learning new things"; "Curiosity"; "Searching for knowledge"; "To train programming", among many other similar answers. In general, all groups have stated that they had knowledge of programming and robotics, liked the area of technologies, programming and robotics, felt motivated to participate in the event, and knew the rules of the First Challenger competition and the majority had never participated in an event of this nature. With this starting point, we intended to find out what changes would occur in the participants after participating in the First Challenger competition.

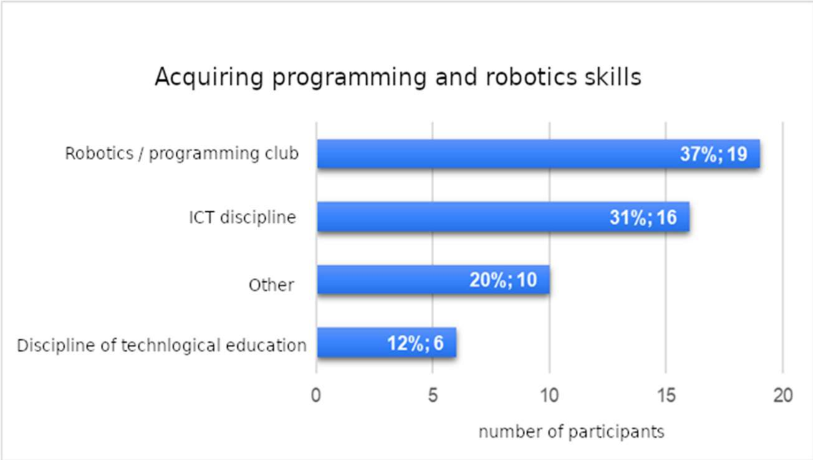

Figure 2. Participants' knowledge acquisition

The first part of this questionnaire was aimed at opinions regarding collaboration and sharing in the search for the answer to the first research sub-question. The second part was related to the ideas and solutions found to guide the answer to the second research sub-question. The third part of the questionnaire focused on the participants' interpretations and information search for decision making in solving the challenges. Lastly, the fourth part of the questionnaire was dedicated to opinions on the First Challenger competition, the possibility of participants pursuing the area of technologies, robotics and/or programming and suggestions that they might consider relevant for the improvement of future events of the competition under study

4.1 Sub-question 1: Collaboration and sharing

Regarding the first sub-question, collaboration and sharing, four closed-ended and one open-ended questions were collected. The data collected was also related to the data from the initial questionnaire. Table 3 visualises the motivation level of the participants during the First Challenger, according to their age. It is shown that 18 participants (90%) remained motivated throughout the challenges, and only 1 participant (5%) was not motivated. By analysing the characteristics of this participant and the answers from the two questionnaires, we can say that he is an older student, attending the 10th grade of school, he liked the field of Technologies, Programming and/or Robotics, working in a team but he was forced to participate saying "Teacher made me".

Table 3. distribution of the degree of motivation of the participants during the First Challenger.

description	10 - 12	13 - 15	16 - 18	> 18	total
	n | %	n | %	n | %	n | %	’n | %
1 - I strongly disagree	0 | 0	0 | 0	0 | 0	0 | 0	00 | 0
2 - I partially disagree	0 | 0	0 | 0	0 | 0	1 | 5	01 | 5
3 - Indifferent	0 | 0	0 | 0	1 | 5	0 | 0	01 | 5
4 - I partially agree	1 | 5	8 | 40	2 | 10	3 | 15	14 | 70
5 - I totally agree	1 | 5	0 | 0	1 | 5	2 | 10	04 | 20

(Note: Each column shows the number and percentage of participants)

When we compare the graphs of initial motivation (Figure 3) and throughout the challenges (Figure 4) we can see that despite the oscillations, the participants remained motivated throughout the First Challenger, with the 10-12 and 13-15 age groups being the most motivated over time.

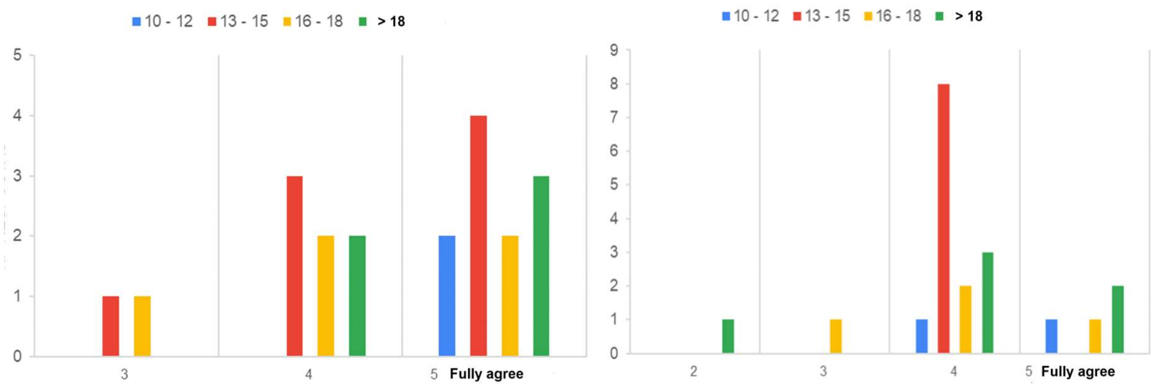

Figure 3. B. Initial motivation of participants, A1 Participants’ motivation during the challenges

The participants who considered to have become fully motivated, initially and during the activities, had prior knowledge of programming or robotics; acquired either through ICT, Technological Education, or their school’s club; they liked the area of Technologies, Programming and/or Robotics; they enjoyed working in a team and had reached level 1 of the First Challenger. Although, they mentioned that the motivation for their participation was based on "Learning"; "Programming"; "It was my liking for robotics and programming" , but they also make clear that the greatest difficulty felt was in "Programming" and with the "Colour Sensor".

The trend that can be seen in the graphs is that the younger students maintained a higher level of motivation throughout the competition. During the participation in the test, the collaboration of the participants to solve the challenges, according to their ages, is reported in Figure 4 to 6. It was possible to verify that most participants collaborated strongly in groups to share and apply their knowledge to solve the challenges.

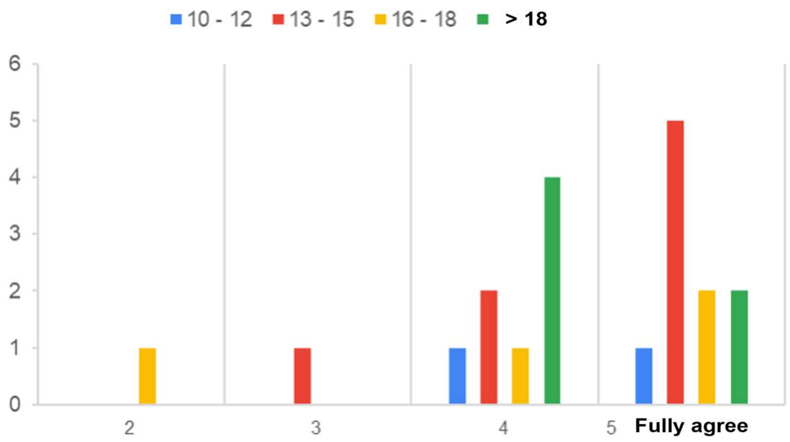

Figure 4. Intra-group collaboration competence in solving the challenges

Analysing data in Figure 4, the students who indicated that they had collaborated with their team members in solving problems were motivated during the competition; they mentioned that they liked the area of Technologies, Programming and/or Robotics, and they were likely to follow this area during their future career. They had knowledge of programming and robotics and mentioned that the motivation for participating in the First Challenger competition would have been: "It was my liking of robotics and programming that motivated me to come here"; "Because it was a new experience that can help me in the future"; "I thought it was a good new experience, and it would be fun."

Figure 5 shows that almost all participants reported that they had improved their teamwork skills. The participants who reported that have felt an improvement in their teamwork skills also like the area of Technologies, Programming and/or Robotics, have knowledge of these areas, and they collaborated/helped their teams in solving the challenges; followed the robot assembly manual and understood/reformulated the robot programming; and they were rewarded by reaching level 1 of the First Challenger competition.

In the questions represented by Figure 4 and Figure 5, only one participant answered negatively on both questions. This participant was between 16 and 18 years old; attended secondary school; reported that his teamwork skills did not improve; did not collaborate in sharing ideas and solving problems either with his group or with other groups; did not always feel motivated; reported that he had difficulties in programming, but his team reached level 1 of the competition. This participant, in the initial questionnaire, indicated that he liked teamwork, and that he had previous knowledge in the area, but he mentioned that he didn't like the area of technologies, programming and robotics.

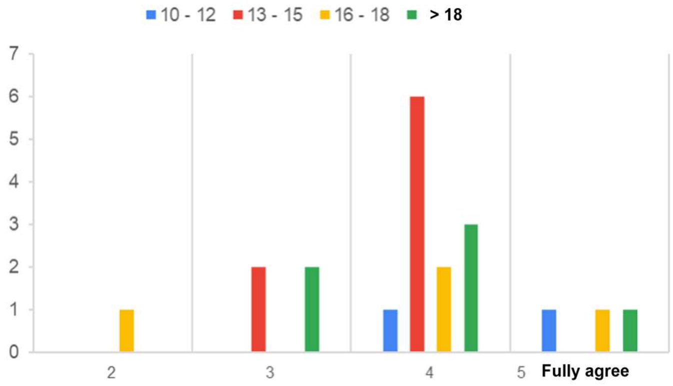

Figure 5. Team-working skills

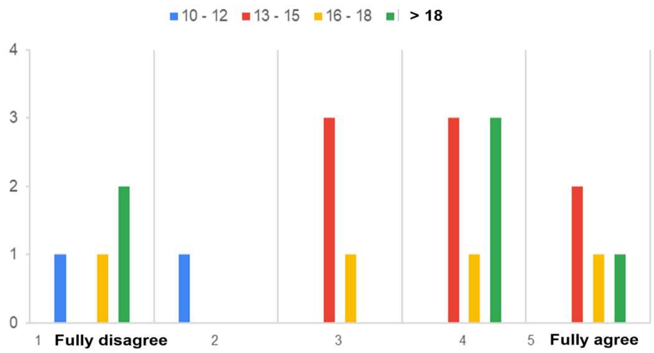

Figure 6. Collaborating and sharing competence with other teams

Finally, Figure 6 shows that the participants who reported not having collaborated and shared ideas outside their own team stated that they enjoyed working in a team and had never participated in a robotics event. The youngest participants (10-12 years old) were the ones who, contrary to motivation, revealed greater difficulty in interacting with other participants, either because not all the elements had programming knowledge or because they were new to this kind of event. On the other hand, the participants who reported having collaborated or shared ideas with other teams were motivated throughout the competition; improved their teamwork skills; helped their team to solve the challenges; and had knowledge in programming and robotics.

In short, it was found that participants with prior knowledge would be more prepared to perform the activities. However, given this research, this is especially true when accompanied by age maturity. According to the analysis, it is important that participants have knowledge about the activities they will develop, namely the basic rules and concepts of robotics, thus clubs or subjects that explore the concepts of the area are relevant. It should also be noted that contact with this type of event and collaborative skills may be factors that sustain motivation.

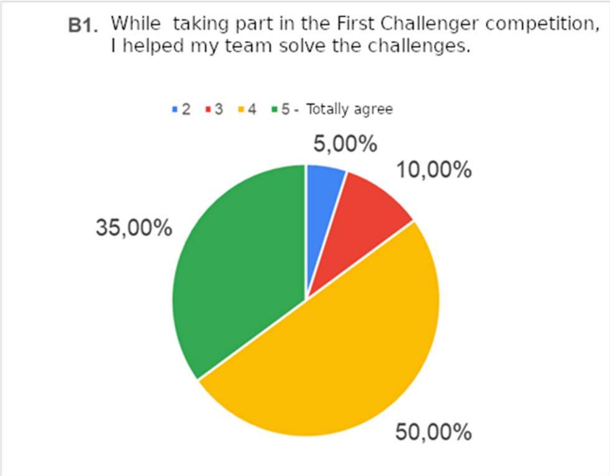

Figure 7. Collaborating and sharing competence within the team

4.2 Sub-question 2: Presentation of ideas and solutions

Through the analysis of figure 7 most participants (85%) considered that they helped their peers in solving the challenges. However, it should be noted that the collaboration of the participants towards the other competing teams was variable in its attributions, as shown through table 4.

Regarding the greatest difficulties experienced by the participants when working with their team, most pointed to programming and the use of the colour sensor. When asked how they solved the challenges among themselves, we obtained answers such as "Building the robot"; "Giving ideas and helping with programming and construction"; "Giving ideas that I found; testing the motors/sensors/etc."; "Thinking"; "Being present at each obstacle"; "Soldering"; "Teamwork with knowledge and ideas" and "I didn’t help".

To solve the challenges, it was found that collaborative skills are fundamental to the objectives to be achieved, but without prior knowledge it can lead to degrees of difficulty that mitigate an active intervention in the collaborative learning process, sharing ideas and helping peers. Once again, we stress the importance of exploring the basic concepts in schools.

Table 4. Distribution of the degree of motivation of the participants during the First Challenger.

description	10 - 12	13 - 15	16 - 18	> 18	total
	n | %	n | %	n | %	n | %	’n | %
1 - I strongly disagree	1 | 5	4 | 20	1 | 5	1 | 5	7 | 35
2 - I partially disagree	1 | 5	0 | 0	0 | 0	0 | 0	1 | 5
3 - Indifferent	0 | 0	3 | 15	1 | 5	1 | 5	5 | 25
4 - I partially agree	0 | 0	0 | 0	1 | 5	3 | 15	4 | 20
5 - I totally agree	1 | 5	1 | 5	1 | 5	1 | 5	3 | 15

The competitive nature of the event may lead participants to collaborate only with their team, avoiding collaborating with others. In this sense, and according to the data collected, it can be said that competition promotes some obstacles about general collaboration, which, in turn, can reduce the sharing of ideas between elements, even outside their teams. However, we can’t ignore the fact that this behaviour may be due to a lack of solid knowledge to enable collaboration and the sharing of ideas because they don’t feel at ease.

4.3 Sub-question 3: Interpretation of information and decision-making

The participants were asked how to use the AZORESBOT robot construction manual produced by the organisation. Only one participant said he hadn’t used it to build the robot. This student had previous knowledge of programming and robotics, said he didn’t like the area of technology, programming and/or robotics and, also said that he hardly collaborated with his team.

But is the existence of prior knowledge important for the way students approach the problem, helping them to decide, or, put another way, does the students’ lack of experience prevent them from understanding and reformulating the programme presented to them to solve the challenge?

When asked how well they understood, used and could reformulate the programme presented and made available by the organisation, 4 participants (20%) said that they understood the programme very little and that their ability to reformulate it was low (see Figure 8). On the other hand, 12 participants (60%) had a better understanding of the programme.

Regarding the achievement of the implementation stages of the competition it was shown that all participants (100%) completed the first stage of the challenge - following the line, 6 participants (30%) also completed the second stage following the line and colour detection and seven participants (35%) completed the third stage - following the line, colour detection and tunnel (Figure 9).

Students who completed the last challenge were attending secondary school, they mentioned that they had previous knowledge in programming and robotics, their schools have a programming and robotics club, and they all enjoy the area.

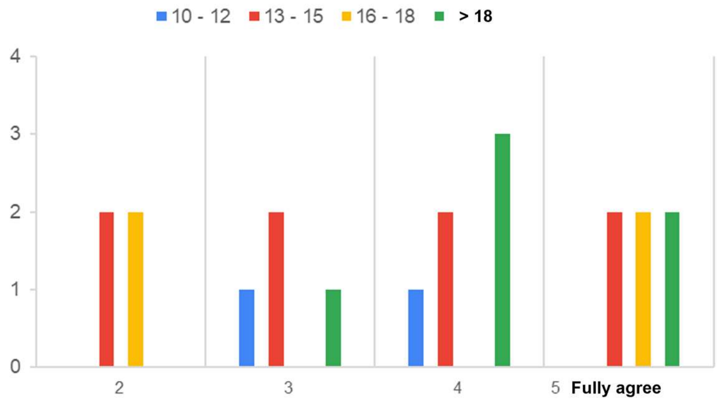

Figure 8. Understanding and redesigning programming

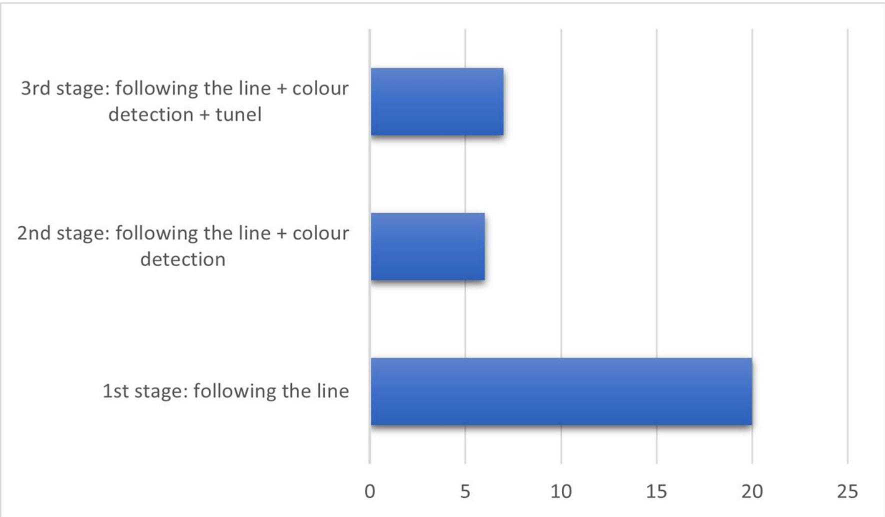

Figure 9. First Challenger competition

They felt motivated and their degree of motivation remained high during the challenges, as did the degree of collaboration with their own team members. The strategies used by the participants to make changes to the assembly or programme the code was varied. Prior knowledge, once again, becomes fundamental to the understanding and application of programming and robotics concepts. Without them, the difficulty can be high and lead to a low capacity to make decisions and reformulate the available content.

In this research study, the last part of the questionnaire was completed with other questions concerning the positive aspects of the event, the possibility of interconnecting the area with their academic and/or professional career and suggestions that the participant considers relevant to mention. Regarding the positive aspects, the participants considered the development of learning and application of knowledge - "We learned more"; "Adding knowledge about robotics and programming" - even considered fun for the participants - "New experiences that were quite fun", "It was fun".

In this competition, the teams participated in order to develop collaborative skills for the goal to be achieved, *i.e.* “The teamwork”. Even so, persistence and the possibility of correcting errors were aspects that the participants considered essential, to improve their learning, apply the knowledge and achieve the intended objectives - "The possibility of having 2 attempts, being able to correct some errors"; “Possibility of repeating the test” and ‘The collaboration”. For suggestions on the event held only suggested the quality of the materials used “Please arrange materials with more quality”.

4.4 Discussion

The older participants were the ones who presented the greatest ability to develop the challenges. In Esteves [11] when investigating the motivation for learning and creativity, in the 3rd and 4th years of elementary school, although in a classroom context, demonstrated that the success and interest of students in programming and robotics was dependent on the student’s level of maturity and their ability to develop activities. In learning and exploration of concepts that may have some degree of complexity and abstraction “if students face the syllabus with difficulty, these will not enhance their motivation for learning, thus creating a barrier to their involvement with programming and robotics”.

In this context, we believe that the First Challenger competition, given the assembly and programming characteristics of the robots, should be rethought regarding the levels of education to be applied. In other words, the AZORESBOT robot presented a high degree of difficulty, both in terms of assembly and programming for a middle school age group of less than 12 years old. It is more suitable for secondary school students.

Even so, it is worth mentioning that from our perspective, it is fundamental to implement a robotics discipline in basic education and to develop related activities.

In the context of programming and/or robotics clubs, attention should be paid to relevant considerations of students’ developmental stages, namely regarding the degree of complexity and abstraction, since abstraction, logic and complexity depend on their age groups [17]. In general, students aged between 7 and 11/12 years show a “capacity to mentally elaborate the perceptions obtained from the environment, in a logical and coherent way” and students at older ages initiate a capacity to ‘reason about hypotheses, as they become able to deal with abstract concepts and perform mental operations through them, according to formal logic” [6].

However, we also corroborate that the First Challenger is a robotic competition, in a playful environment, capable of providing learning and an understanding of a reality that recognises the participant as a ‘thinking being, and therefore values the challenge that promotes reflective knowledge and organised knowledge” [22] (p.837).

5 Conclusions

The results of the survey study suggest that the First Challenger competition promotes the development of collaboration and sharing of skills and also the presentation of ideas and solutions and the interpretation of information and decision-making.

The results also show that students from elementary and middle school prefer to have the robot previously assembled, or of easy assembly and with preconceived algorithms only for introductory knowledge in programming. High school students, with developed abstract abilities, have better conditions to solve problems, both at the programming and robotic construction levels.

We also believe that the competitions should promote collaboration, not only between teams but also among different teams. Although First Challenger presents potentialities to foster the so called 21st-century skills it lacks ways to motivate and promote more collaborative behaviours with participants because of its design.

We consider that playful robotics applied in open robotics is a way to involve and integrate students in a technological world promoting learning and memorable experiences.

However, we also consider that the existence of clubs can be a space, open to all but not everyone may have the opportunity to attend it, so it may limit the development and knowledge in the area. The discipline of programming and/or robotics can overcome this limitation and be a universal and accessible learning space for all. As a result, the sample used was of limited dimension.

We identified the following limitations in this research: the open- and closed ended questionnaires were optional and free for participants, which only led to the analysis of certain questions; not all participants answered the final data collection questionnaire and others did not give their consent.

For future investigations, we suggest studies that verify principles for the motivation of participants regarding programming and robotics in events like the AOR. The application of tangible and programmable objects, according to the age groups of the students, for the activities to be developed in future competition events should be the object of investigation. We also suggest investigating the role of the tutor and the importance of students’ prior knowledge for better success in the activities to be developed. Finally, competition can be seen as a barrier to collaboration outside their own teams. However, we believe this statement lacks further research to validate the statement resulting from this study.

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