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An Educational Robotics Course: Examination of Educational Potentials and Pre-service Teachers' Experiences

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Abstract

Educational robotics is a very important instrument because it provides an active learning environment and allows learners to acquire 21st century skills. Teachers need to use this instrument in teaching the science of robotics as well as in helping students master the subject and gain experience. This study aims to reveal pre-service teachers' perceptions and experiences in an educational robotics course. Specifically, the satisfaction, motivation, enjoyment, collaboration, and challenge (SMECC) levels of participants were investigated in this robotics learning process. In addition, pre-service teachers' engagements were revealed. The participants were 30 pre-service teachers. A post activity survey, observation, and interview were used as data collection tools. This study adopted a mixed method approach. The pre-service teachers showed a high level of satisfaction, motivation, enjoyment, and collaboration and also showed no difficulty doing the robotics activities in general. Moreover, strong relationships were found among satisfaction, motivation, and enjoyment. The findings indicated that the ER activities provided an edutainment learning environment and that pre-service teachers were highly engaged in the robotics activities. The most motivating factor for the pre-service teachers was teaching what they had learned about the science of robotics to their future students. The pre-service teachers' experiences and engagements are revealed in detail and also discussed. Suggestions are presented here for guiding future educational robotics studies in the context of pre-service teachers' education.

Introduction

In recent years, studies in the educational technology field have brought attention to new environments and instruments for the teaching of robotics. This kind of interest is called educational robotics (ER). It has been observed that interest in robotics has been increasing (Benitti, 2012). ER allows students to learn subjects through experimenting with a 3D real world in a more natural way (Mitnik, Recabarren, Nussbaum, & Soto, 2009). Several studies have shown that ER can develop skills such as problem-solving, critical thinking, decision making, teamwork, and science process (Eguchi, 2014; Mauch, 2001). All of these skills are essential for operating in the workplace of the 21st century (Alimisis, 2013). Moreover, ER has become popular in teaching Science, Technology, Engineering, and Mathematics (STEM) because ER activities enable real-world applications of engineering and technology and help students to understand the abstract nature of science and mathematics subjects (Nugent, Barker & Grandgenett, 2012). In sum, ER activities have a potential impact on students' learning of STEM students as well as their personal development.

Background of Educational Robotics

Constructivism and constructionism are two main theories behind ER. Piaget argued that manipulating artifacts is the key for children as they construct knowledge (Piaget, 1974). Papert developed a theory based on Piaget's constructivism. Papert believed that knowledge construction happens most effectively in a context where the learner is consciously engaged in constructing a public entity, whether it is a sand castle on the beach or a technological artifact (Papert, 1980). ER is strongly related to Papert's vision of constructionism. According to the constructionist theory, knowledge is not just simply transferred from teacher to student. It is constructed in the mind of the student through active learning (Harel & Papert, 1991). When students actively engage in producing external artifacts, they can create new ideas and share them with others (Lindh & Holgersson, 2007). Papert was the first educational researcher to use the earliest implementations of Logo in allowing students to build a machine out of Lego pieces and to write a program to control the machine (Resnick, Ocko, & Papert, 1988). Since then, his studies using ER have become a popular topic (Goldman, Eguchi, & Sklar, 2004). ER can be a great tool for students to use in constructionist learning experiences (Alimisis, 2013; Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013). In addition, students have an opportunity to learn and utilize programming languages and receive immediate feedback. As stated by Papert: "Given a good programming language, I see children struggling to make a program work in a way that they seldom sweat at their paper-and-pencil mathematics" (Papert, 1999, p 4). Therefore, ER activities may be beneficial for improving the STEM skills of students. There are several studies in which ER has been used in other fields such as mathematics (Hussain, Lindh, & Shukur, 2006), science (Barak & Zadok, 2009), engineering (Hobbs, Perova, Rogers, & Verner, 2007), and physics education (Williams, Ma, Prejean, Ford, & Lai, 2007; Martinez Ortiz, 2011) at all education levels.

Educational Robotics Kits

Various educational robotics kits have been developed by several companies to teach robotics to students. These kits are an inestimable tool for teaching robotics to students from kindergarten to K-12, and they serve as learning tools to ensure fun, hands-on activities in an attractive learning environment and promote students' interest and curiosity (Eguchi, 2010). Educational robotics kits generally contain batteries, geared motors, servo motors, various sensors, LEDs, colored plates, pin holes, pins, Bluetooth modules, cables, switches, and remote controllers. These kits can be divided into two classes: versatile and non-versatile. Versatile kits are modular and expandable and allow for ease of re-use, while non-versatile kits are for building only one robot. Therefore, versatile kits are more often used in education.

The Lego company has been developing various kits such as Creator Block, Technic, and Mindstorms for ages 4 to 12 and up. Robotis has also been producing various types of educational robotics kits. The company's name is derived from the question, "What is a robot?" (Thai, 2015). This company's kits, named Ollo, Dream, Bioloid, Mini, and GP, are designed for children ages 4 to 15+. Unlike the other companies' competing products, Robotis' kits include a curriculum and guidebook for their curriculum activities. Therefore, the Robotis Dream kit was chosen for this study in order to focus on the evaluation of the robotics design process.

Educational Robotics Courses for Pre-service Teachers

Educational robotics courses have been increasing in popularity worldwide (Bruder, & Wedeward, 2003; Hadjiachilleos, Avraamidou, & Papastavrou, 2013; Kay, Moss, Engelman, & McKlin, 2014; Kim et al., 2015; Sullivan & Moriarty, 2009). The professional development for teachers on robotics is considerable and trains teachers on how to teach robotics and how to integrate ER into other fields. These kinds of courses provide teachers with basic knowledge and skills about ER and show them pedagogical approaches to designing ER environments. Undoubtedly, Teacher Training Institutions (TTI) are ideal places to teach these courses. Some TTIs present workshops or courses for pre-service teachers.

Research results have shown that becoming familiar with Lego pieces motivated pre-service teachers to make scientific inquiries (Hadjiachilleos et al., 2013), and their confidence in both learning and teaching programming languages increased after their participation in workshops on robotics (Kay et al., 2014). These courses influenced pre-service teachers' pedagogical beliefs toward teaching ER as well (Sullivan & Moriarty, 2009) and improved their STEM engagement and emotional engagement (Kim at al., 2015). Learning how to design ER courses should enable pre-service teachers to work with other colleagues to create organizations that support learning (Adnyani, 2015). However, most studies on ER courses do not present enough information to pre-service teachers on how to design ER courses. And there have not been many studies done yet on evaluating these courses. Therefore, many teachers are not aware of the benefits of educational robotics, and those who are aware of them are still not prepared to teach robotics.

Rationale and Importance of the Study

In this study, an ER course was designed for pre-service teachers and the process of the course was examined in terms of pre-service teachers' satisfaction, motivation, enjoyment, collaboration, and challenge (SMECC), which are the most important factors of the learning process. Satisfaction is one of the key factors in learning. A student's level of satisfaction is directly related to his or her ability to learn (Ray, Sormunen, & Harris, 1999;

Simon, 2000). Motivation is another important factor that contributes to the learning process. Motivated students are explorative, self-regulated, and aligned for deep level processing. Self-motivation could be considered one of the keys for success (Ruiz-del-solar & Aviles, 2004). Student enjoyment in learning activities is also connected closely to the level of student self-attribution of success (Spaulding Cheryl, 1992). Collaboration provides active and effective learning (Michaelsen, Knight, & Fink, 2002); team activities may help students enjoy tasks more (Gomez, Wu, & Passerini, 2010). In addition, ER activities provide experiential, hands-on learning which make such activities motivating and enjoyable (Kim et al., 2015; Nugent, Bradley, Grandgenett, & Adamchuk, 2010). Students are faced with challenges during hands-on learning activities in ER courses (Jormanainen & Sutinen, 2014). Therefore, these factors are the basis of effective learning during robotics activities, and an examination of them in detail can provide valuable information for integrating ER into future classrooms.

Another important factor in learning is personal engagement. However, there is little research that examines the engagement processes of pre-service teachers in ER courses (Kim et al., 2015). In this study, pre-service teachers' engagement process was examined based on a classroom engagement framework (Fredricks, Blumenfeld, & Paris, 2004; Reeve & Tseng, 2011). According to this framework, there are four types of student engagement in the learning process: behavioral, emotional, cognitive, and agentic. Behavioral engagement refers to students' attention, effort, and persistence in the learning process, and it increases cooperative and active learning opportunities. Emotional engagement is the presence of positive emotions and indicates this type of engagement during learning activities. As stated by Taylor and Statler (2013), less emotion means less learning and much more emotion means much more learning. Emotional engagement encourages students to assume responsibility towards one another and motivates them to complete the activity (Jamaludin & Osman, 2014; Jones, 2012). Cognitive engagement is related to using strategic, sophisticated learning strategies during activities.

The last type, agentic engagement, means helping students to learn from their mistakes and encouraging them to seek feedback. If students are agentically engaged, they add their behaviors, feelings, and thoughts into the flow of the instruction (Reeve, 2013). So enhancing these four types of student engagement promotes active learning. This study is aimed to obtain measurable evidences that would lead to an understanding of how teachers engage in, learn about, and use robotics for teaching in their future classrooms. Since there is lack of previous research on elementary pre-service teachers, it is of significance to research their learning process of robotics and its potential implications for their future students on teaching robotics regarding their training.

This study aims to reveal pre-service teachers' perceptions and experiences in an ER course. The following research questions are addressed:

1) *What are the satisfaction, enjoyment, motivation, challenge, and collaboration levels of pre-service teachers in an ER course?*
2) *Are there relationships among satisfaction, motivation, enjoyment, challenge, and collaboration in an ER course?*
3) *What are the pre-service teachers' learning experiences in an ER course?*
4) *How do pre-service teachers engage in an ER course?*

Methods

In this section research design, participants' information and research process are detailed. Moreover, data collection tools and data analysis are explained.

Research Design

In this study, a concurrent triangulation, mixed-methods design was used in investigating the research questions. The study was also based on the principle of using quantitative and qualitative methods together and simultaneously (Creswel, 2014). Therefore, the following quantitative and qualitative data were collected concurrently from multiple sources: (a) post activity surveys, (b) observation forms, and (c) interviews. There was an equal balance between the quantitative and qualitative methods.

Participants

The participants were 30 pre-service teachers (23 female, 7 male; 20-22 years old) who were taking an ER professional development course called "Robotics in Education I" in the TTI of a large university in Turkey. This course was an elective course. Participants will be teaching in elementary schools in future. All participants were attending the course voluntarily as part of their professional development.

Research Process

The course was designed to meet four hours each week and it took ten weeks. The course activities were chosen from Robotis Dream (RD) ER kits, which contain batteries, geared motors, servo motors, various sensors, LEDs, colored plates, pin holes, pins, Bluetooth modules, cables, switches, and remote controllers. Each RD kit includes several kinds of activities which help users to understand the principles of movement, speed and force, leverage, elasticity, and inertia, etc. RD enables students to create bipedal, quadruped, hexapod, and other kinds of robots. RD has four levels, each with its own guidebook. The activities from the first and second levels of the RD kit were selected for the course so as to focus on the design process of ER. Assembly of bricks and motors, principles of movement, use of sensors, and an introduction to algorithms were taught in the course. The participants were divided into random groups of three to four people from different departments. The groups were called G1, G2, …, G10. Each group had one ER kit and worked cooperatively. Participants designed robotics activities by following steps in the Robotis Dream guidebook. This guidebook contains designing steps from part to whole of robots based on procedure teaching. Moreover, the participants carried out their robot designs based on creative thinking spiral model in final project. At the beginning of the course, the instructor introduced theoretical insights (how sensors work, principles of movement, algorithms, etc.) into the related activity and then the groups designed a robot following the steps in the guidebook. The details of the activities during the course are given in Table 1.

Table 1. Activities during the study

Week	Subject	Target	Educational Robotics Kit Level
1	Introduction to robotics (Squirrel Robot)	Learning the pieces in the robotics education kit and making the squirrel robot acquire psychomotor skills by combining these pieces.	Level 1
2	A1. Generating electricity with your hand (Windmill Robot)	Making the windmill robot generate electric energy from kinetic energy by making use of the switch, geared motor, li-ion battery, and lead pieces.	Level 1
	A2. Rotating and pushing (Whale Robot)	Making the whale robot convert rotational energy to pushing energy.	Level 1
3	A3. What is the center of gravity? (Brachiosaurus Robot)	Making the Brachiosaurus robot walk on four legs according to the principle of the center of gravity.	Level 1
	A4. Jump jump (Rabbit Robot)	Making the rabbit robot move by jumping with rotation and pushing power.	Level 1
4	A5. What is the advantage of walking on six legs? (Ladybug Robot)	Making the ladybug robot walk on four legs according to the principle of the center of gravity.	Level 1
5	A6. Seeing objects through light reflection (Avoider Robot)	Making the avoider robot move by avoiding obstacles with the help of infrared sensors and designing algorithms.	Level 2
6	A7. Sound spreads (Seal Robot)	Making the seal robot detect the sound of clapping and moving according to the number of clapping and designing its algorithm.	Level 2
7	A8. Sudden stops (Puppy Robot)	Making the puppy robot keep on the line by perceiving black lines with the help of infrared sensors.	Level 2
8	Final project	Pre-service teachers designed their own robots suitable for elementary school level with the knowledge and skills they acquired in the group during the lessons.	Level 2
9-10	Project Presentations	Pre-service teachers presented in the class the robots they designed.	

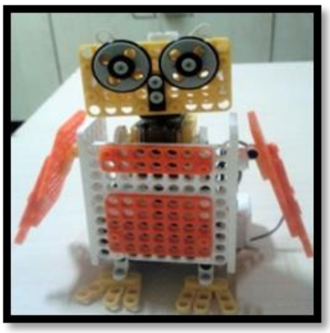
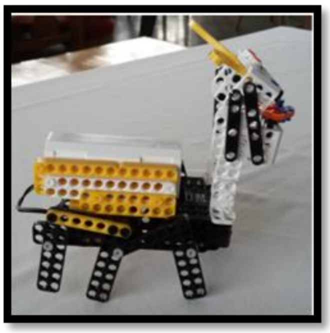
The collaborative activities were designed in accordance with the constructivist learning approach. The teacher assumed a guidance role and the instructor helped participants who had challenges with the process. During the weekly classes, the researchers collected data using structured observation forms. Then the participants filled in a post activity survey at the end of each activity. All of the groups had to disassemble the designed robots at the end of the course because the materials in the kit were needed for the next robotics activity. During the course, participants completed eight robotics activities and one final project, which was their own custom-designed robot. Since the participants would work at elementary schools, all activities were at elementary school education level. Figure 1 shows pictures from the course.

Figure 1. Pictures from the robotics activities

For the final project, the groups created their own robots to use for educational purposes determined by the pre-service teachers. They followed steps of Creative Thinking Spiral Model to develop their own robots. This model includes five stages; imagine, play, share, reflect, and the next expended creative thinking spiral. The groups imagined what kind of educational robot can be designed for elementary school level. They created a project based on their ideas. They tested and played with their creations. Then they shared their project with their classmates and instructor. Subsequently, they reflected on their whole experience which led them to imagine new ideas and new projects.

During this process, pre-service teachers developed and refined their abilities as creative thinkers and also learned to develop their own ideas, try them out, and generate new ideas based on their experiences (Resnick, 2007). The robots had different movement features based on the educational scenarios created. Pre-service teachers constructed algorithms and programmed the robots along with the instructor. Following this, the robots were presented to the other groups at the end of the course. The pictures of some of the robots created for the final project are presented in Table 2.

Table 2. Some final projects of the pre-service teachers

		
G1	**G2**	**G4**
Chick robot which can bend its neck according to the clapping count to catch food in the container and go back to its coop at one clap.	Owl robot which can turn its head 180 degrees.	Bull robot which can detect the red color and go toward the red color.
		
G5	**G6**	**G10**
Clown robot which can walk and repeat it with one clap.	Pianist robot which can detect different colors and play melodies according to color.	Dog robot which can follow its owner's steps, turn quickly toward the clapping, and stop when it sees its owner.

Data Collection Tools

In this study, a post activity survey (Appendix A) and observation (Appendix B) and interview forms (Appendix C) were used as data collection tools. The post activity survey was adopted from a similar study conducted by Mitnik at al. (2009) and consists of five Likert questions and one open-ended question. It includes five questions to reveal participants' levels of satisfaction, motivation, enjoyment, challenge, and collaboration during class activities. The survey questions are: How satisfying was the activity? How motivated did you feel during the activity sessions? How enjoyable was the activity? How challenging was the activity? Throughout the activity, how much did you collaborate with your teammates? The possible answers to the survey's questions go from Very Little to Very Much. This survey applied end of the ER activities each week.

The observation form was created based on previous studies examining pre-service teachers' engagement in the learning process (Kim at al., 2015; Reeve, 2013; Skinner, Kinderman, Connell, & Wellborn, 2009; Skinner, Kindermann, & Furrer, 2009). It was focused on the four factors that showed the engagement of pre-service teachers in robotics activity settings. The framework of the classroom observations is presented in Figure 2. For each robotics activity, pre-service teachers' behaviors were coded and detailed notes were recorded by two observers. The group based observations were conducted. Also, the interview form was constructed based on the literature revealing pre-service teachers' experiences in designing educational robotics.

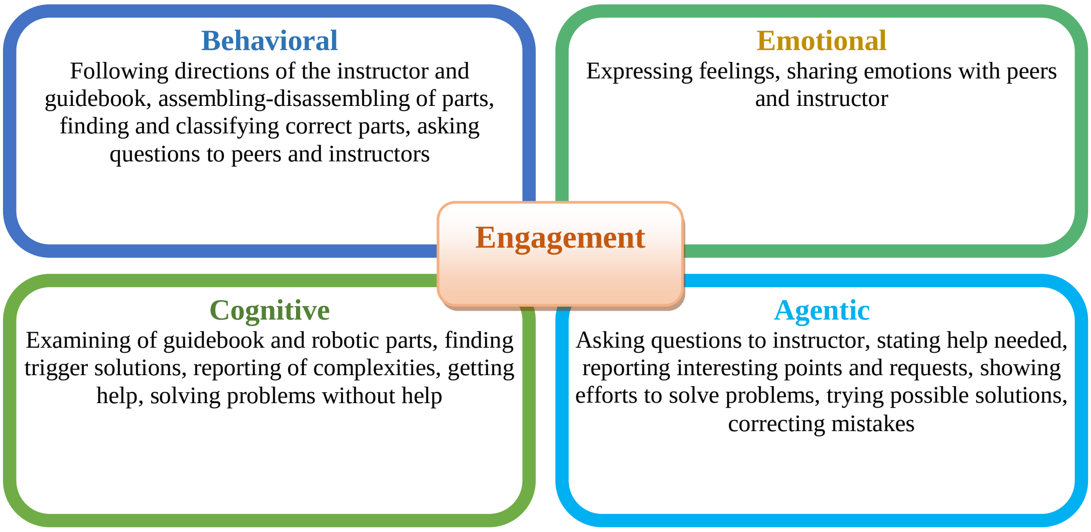


Figure 2. The framework of classroom observations

Data Analysis

Descriptive statistical methods were used in analyzing the weekly post-activity surveys. The relationships among satisfaction, motivation, enjoyment, challenge, and collaboration (SMECC) were examined with correlational analysis. All assumptions of correlation were verified (Pallant, 2007). Qualitative data obtained from observations and interviews were analyzed with descriptive and content analysis methods. Several measures were taken to ensure the validity of the study and the data collection process. Two researchers designed robotics activities in the educational course together and conducted the research process systematically. Data collection tools were developed based on the literature and on three experts' views. During the qualitative analysis process, the researchers studied together and they determined the themes, categories, and codes according to content analysis. Moreover, all categories and codes were checked by a different field expert in terms of clarity and comprehensibility.

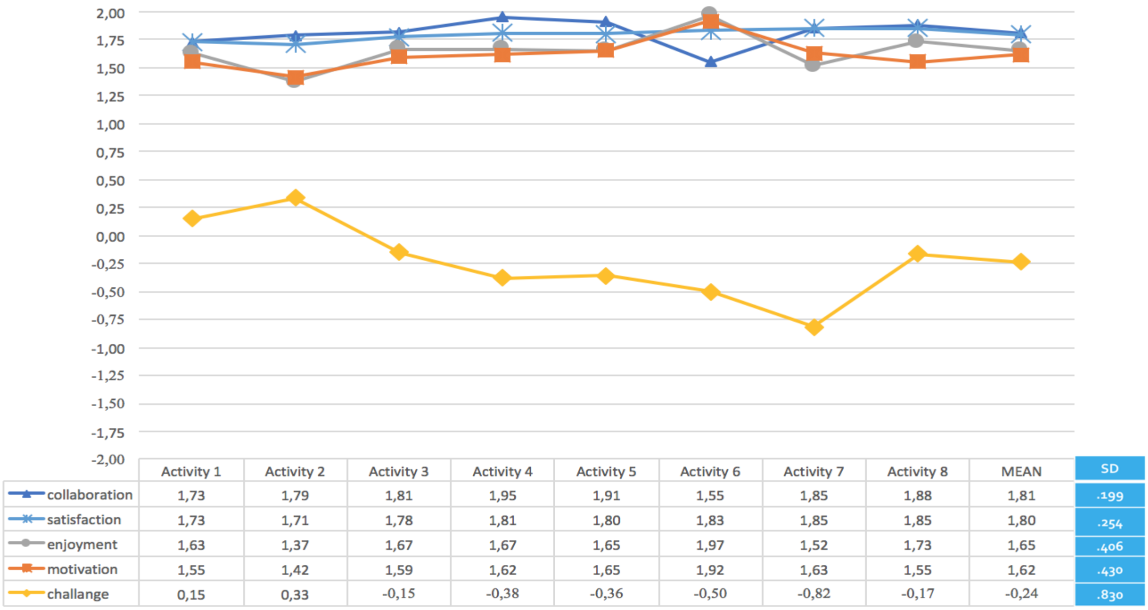
Findings

The findings of the post activity survey of the pre-service teachers, the mean values of the dimensions of SMECC, and the relationships among the dimensions are presented here with diagrams and tables. In addition, findings from the observations and interviews are presented here with frequency values and direct quotations of the theme, code, and categories.

SMECC Levels of Pre-service Teachers for Each Activity

The pre-service teachers' perceptions toward each robotics activity were revealed based on SMECC dimensions. In Figure 3, the SMECC levels of the participants for each activity are shown. The details of the activities are shown in Table 2.

As seen in Figure 3, the pre-service teachers had a high level of collaboration (M=1.81), satisfaction (M=1.80), enjoyment (M=1.65), and motivation (M=1.62). Also, they did not report too much challenge (M=-0.24) during the activities in general. When the pre-service teachers' perceptions of each activity were examined, even though the collaboration level of the groups decreased in the sixth activity (M=1.55), this level increased regularly in general. And even though the enjoyment level was relatively low in the second activity (M=1.37) and in the seventh activity (M=1.52), this level was at its highest (M=1.97) in the sixth activity. Also, the satisfaction level increased regularly. The satisfaction reached the highest level in the seventh and eighth activities (M=1.85). Even though the motivation level was relatively low in the second activity (M=1.42), it was at its highest level in the sixth activity (M=1.92). The challenge level was relatively high in the first activities, and then it decreased regularly up through the last activity. The lowest level of challenge was in the seventh activity (M=-0.82).



	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7	Activity 8	MEAN	SD
collaboration	1,73	1,79	1,81	1,95	1,91	1,55	1,85	1,88	1,81	.199
satisfaction	1,73	1,71	1,78	1,81	1,80	1,83	1,85	1,85	1,80	.254
enjoyment	1,63	1,37	1,67	1,67	1,65	1,97	1,52	1,73	1,65	.406
motivation	1,55	1,42	1,59	1,62	1,65	1,92	1,63	1,55	1,62	.430
challange	0,15	0,33	-0,15	-0,38	-0,36	-0,50	-0,82	-0,17	-0,24	.830

(The possible highest mean= 2 and lowest mean= -2)
Figure 3. SMECC levels of pre-service teachers for each activity

Relationships among SMECC Dimensions in the Robotics Activities

When the relationships among satisfaction, motivation, enjoyment, challenge, and collaboration in the robotics activities were examined, a strong relationship was found among satisfaction, motivation, and enjoyment. Also, it was found that moderate negative relationships existed among challenge, motivation, and satisfaction. Detailed data are provided in Table 3.

Table 3. Relationships among SMECC dimensions in the robotics activities

	Satisfaction	**Motivation**	**Enjoyment**	**Challenge**	**Collaboration**
Satisfaction	1	.600**	.795**	-.362 *	.305
Motivation	.600**	1	.781**	-.370*	.249
Enjoyment	.795**	.781**	1	-.352	.273
Challenge	-.362*	-.370*	-.352	1	-.175
Collaboration	.305	.249	.273	-.175	1

** p< .01 ; * p< .05

Pre-service Teachers’ Experiences in Robotics Activities

Pre-service teachers’ experiences in the robotics activities were revealed following the analysis of the in-depth interviews. According to content analysis, three themes and two categories for each theme were determined (Figure 4).

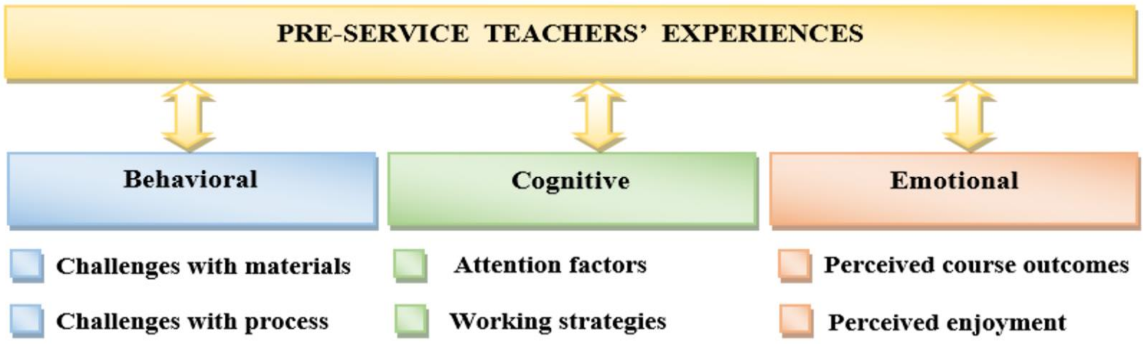


Figure 4. Revealed themes and categories for pre-service teachers' experiences

Behavioral Experiences

As seen in Table 4, the behavioral experiences of the pre-service teachers during the robotics activities were revealed as challenges with materials and challenges with process categories. The participants stated that they had the most difficulty because of wrong assembly, connecting to the wrong port, and the small parts (joints etc.). They complained about assembly issues because the educational robotics kit included tiny detailed parts, and the robots developed in the activities had to be disassembled for the following lesson. Some of the opinions of the pre-service teachers about the challenges in the robotics activities were as follows:

> *"In general, I had difficulty in inserting the cables. I joined the cables coming from the motor and connecting to the microcontroller in the wrong way."* (Female aged 22)
> *"At the beginning, getting used to the little parts like joining the screws was difficult. I coped with this by repeating again and again."* (Female aged 20)
> *"I do not like studs because they hurt my fingertips a lot."* (Female aged 20)

Table 4. Pre-service teachers' behavioral experiences in the robotics activities

Category	Code	f
Challenges with materials	Wrong assembly issues	21
	Connecting to the wrong port	7
	Small parts	5
	Disassembly	4
Challenges with process	Correcting mistakes	15
	Distractibility	4
	Working in groups	3
	Number of activities	2
	Conflicts among teammates	2
	Competition with other groups	1

The main challenges with the process for the pre-service teachers were correcting mistakes, distractibility, and working in groups, in some cases. In addition, some of the participants complained about having two successive activities in each lesson, as well as having competition among the groups. Also, even if correcting mistakes was considered a challenge, at the same time they indicated that it would have been helpful to be able to better understand the working mechanisms of the robots. Some of the opinions of the pre-service teachers about the challenges with the robotics activity process were as follows:

> *"When the robot did not work at the end of the activity, this was the biggest difficulty. When an error occurred, we checked the steps one by one from the beginning."* (Female aged 22)
> *"Spending too much time on correcting mistakes was annoying because I was impatient to see the robot working."* (Female aged 21)

"I disliked making mistakes in the robot making process. However, I can say that making some mistakes and correcting them afterwards helped me to understand the mechanism of the robot. In the beginning phase of the robot, I wanted to finish it immediately and to see the result. So, I hurried up. But, when there was a mistake, correcting the mistake helped me to better understand the working mechanism of the robot." (Female aged 20)

Cognitive Experiences

As seen in Table 5, the pre-service teachers' cognitive experiences were shown to be attention factors and working strategies categories. The attention category included both positive and negative factors influencing the attention of the participants. Within this context, the advantages and disadvantages of working in a group have been emphasized. In addition, participants indicated the time period of the course, enjoyment, and flow as influencing the attention factors. Some of them also specified that attention was negatively influenced when the robot design process had a complex sequence and when there was a competitive atmosphere. Some of the opinions of the pre-service teachers about the attention factors category in the robotics activities process were as follows:

"I was feeling bored when my teammates did not do their steps correctly." (Male aged 21)

"We were not distracted when we focused on all the assembly steps." (Female aged 22)

"Even if I was tired when I attended the class, I was never distracted because these course activities were really fun. It was great to create something by assembling parts.'' (Female aged 22)

Table 5. Pre-service teachers' cognitive experiences in robotics activities

Category	Code	f
Attention factors	Disadvantage of group work	8
	Advantage of collaboration	6
	Time period of the course	6
	Enjoyment and flow	5
	Complex sequence	1
	Competition	1
Working Strategies	**Group**	**18**
	Collaboration	24
	Multiple perspectives	21
	Creativity	13
	Enjoyment	5
	Motivation	4
	Number of teammates	3
	Individual	**8**
	Creativity	3
	Conflict	3
	Control/speed	2
	Both	**4**

The pre-service teachers' working strategies preferences changed and they explained the advantages of their preferences. According to those who prefer to work with a group, group work provides collaboration, multiple perspectives, and creativity. Moreover, working with a group was enjoyable and provided sustained motivation for them. On the other hand, it was suggested that if there are two participants in a group, this might provide a more productive working atmosphere and get rid of the conflicts between teammates. According to those who prefer to work individually, having conflicts between teammates was disturbing. They claimed that when they controlled the process individually, they could be faster and more creative. Some of the participants suggested that working in a group or individual working strategies should be chosen based on the type of robotics activity. Some of the opinions of the pre-service teachers about the working strategies category were as follows:

> *"I prefer working in a group. When each of us assembled different parts of the robot, we finished the activity in a shorter period of time. When I did not understand and I was confused, I was able to consult my teammates."* (Female aged 20)
>
> *"Definitely in a group. During the design process, we were able to realize the mistakes, warn and motivate each other. Working in a group, as it decreased the workload, influenced the process positively."* (Female aged 22)
>
> *"I would prefer to design by myself because I think I can complete the task more quickly and correctly."* (Female aged 20)

Emotional Experiences

As seen in Table 6, the emotional experiences of the pre-service teachers observed during the robotics activities were revealed through the perceived course outcomes and perceived enjoyment categories. Participants indicated that the most important outcomes of the course were designing a robotics course in the future, developing STEM skills, creating tangible things, and improving coding skills. Some of the opinions of the pre-service teachers about the perceived course outcomes were as follows:

> *"When we become teachers, we can teach robotics. Such courses may allow our students to improve their psychomotor skills and cognitive abilities."* (Female aged 21)
>
> *"After this course, it was very enjoyable to develop a robot as a language teaching material. In the future, when I become a teacher, I definitely plan to get an educational robotics kit and use it in my future lessons."* (Female aged 22)
>
> *"I've gained a lot of experience and valuable knowledge about robotics. With this course, I have realized how we can use physics laws in real life. I am able to imagine creating new things such as combining my knowledge from different fields (science, math, programming, etc.)."* Female aged 22)

Table 6. Pre-service teachers' emotional experiences in robotics activities

Category	Code	f
Perceived course outcomes	Learning to teach robotics	13
	Developing STEM skills	8
	Creating tangible things	5
	Improving coding skills	5
	Improving imagination and creativity	4
	Analytical thinking	2
	Multiple perspectives	1
	3D thinking	1
Perceived enjoyment (for activities)	Puppy Robot (Activity 8)	18
	Brachiosaurus Robot (Activity 3)	4
	Avoider Robot (Activity 6)	3
	Seal Robot (Activity 7)	3
	Final Project	2

According to the participants, the most enjoyable activity was the puppy robot (Activity 8), which has infrared sensors and sound sensors and can detect obstacles and follow black lines. Some of the opinions of the pre-service teachers about the perceived enjoyment from the course activities were as follows:

> *"The robot which we designed in the final class was my most favorite activity (Puppy Robot). Different from the others, it has more functions and features with different sensors that enable the robots to follow the line, to stop when it detects an* obstacle, *or to move according to a clapping sound."* (Female aged 22)
>
> *"The activity in which we could detect obstacles with the help of sensors was very good (Avoider Robot). Thanks to the sensors, many great ideas can be generated."* (Male aged 21)

Pre-service Teachers' Engagements in Robotics Activities

The pre-service teachers' engagements were observed according to the classroom engagement framework (Figure 2) during each robotics activity. The participants' engagement with robotics activities was evaluated based on the study groups. It was observed that the engagement of some groups was due to the different aspects of developing strategies during the assembly process. One of the study groups (G10) drew attention to producing effective strategies for reducing the activity completion time by using collaboration. The participants in this group were from the ELT and CEIT departments. Moreover, they had more experience with Lego bricks than the other participants.

Behavioral Engagement

A high level of behavioral engagement was observed overall during all of the robotics activities. There was a high level of collaboration among teammates. At the beginning of the activities, the groups chose the necessary materials using teamwork; thus, the process was accelerated. However, the participants in the groups had to wait for their teammates to complete the assembly steps. The groups usually had difficulty in the assembling and disassembling process at the beginning of the course but this became easier for them in the following weeks as they gained experience. In addition, all the groups tried to finish their activities before the other groups. Therefore, the effect of the competition allowed the groups to maintain a high level of behavioral engagement. G10 was usually the first group to finish the activities; however, the group in which all the participants were male got behind the other groups.

Cognitive Engagement

It took the groups a high level of cognitive effort in order to correctly understand and apply each step in the guidebook. However, they developed different cognitive strategies to accelerate the process. For example, each group had one guidebook, and G10 took pictures of each stage and shared every work step with the other members of the group, which helped them to accelerate the process. As the stages of the robot's construction became more complex, the participants became more collaborative. In addition, as they became familiar with the robotics kit by gaining experience, they had lower cognitive loads and their performance improved. Moreover, the participants became more focused on customizing the robots rather than completing the assembly steps.

Emotional Engagement

The participants seemed to enjoy and flow with the process. They shared their feelings excitedly with their instructor and friends especially after completing the robot. They even took pictures of the robots to share on social media. On the other hand, group members became stressed when their group got behind the other groups. The participants also became discouraged when their robot did not work correctly. In the following weeks, the interest and curiosity of the participants in the design process were triggered through using different parts (motors, gears, sensors, etc.) and features (sound detection, obstacle detection, etc.). Robots which had more features (sound detection, obstacle detection, etc.) were more attractive for them. Moreover, robot competitions (reaching the finish line fastest, etc.) which were arranged after the activities were over increased the level of enjoyment. And the female participants expressed their feelings more than did the male participants.

Agentic Engagement

The groups had problems due to assembling parts in the wrong way, and they asked for help from the instructor in the beginning weeks of the course. However, in the later weeks, the groups could solve such problems with teamwork without the help of the instructor. On the other hand, participants working with advanced level robots faced different kinds of problems (connecting to the wrong port, etc.). These groups used the trial-and-error method to solve such problems first with teamwork, then if this did not work, they solved the problems by asking for help from the groups that had already solved the problem. Otherwise, the instructor used demonstration methods to help groups solve problems.

Discussion

According to the findings, the pre-service teachers were actively engaged in and greatly enjoyed the robotics activities. Most of the participants were satisfied with working as a group and they had a high level of collaboration. The relationship between the pre-service teachers' experiences and the purpose of the robots are revealed in detail. The pre-service teachers' engagement level was high during the activities. The findings of the study are discussed in detail in the following section.

Pre-service Teachers' SMECC Levels in the Robotics Activities

The pre-service teachers were highly collaborative and they did not have too many challenges during the robotics activities. However, regarding the SMECC levels of each activity, the collaboration level decreased when the members of the group worked alone (because other team members did not attend class for some reason such as illness). On the other hand, it was observed that the level of challenge was moderate in the beginning while it decreased progressively in the successive activities. This can be explained by the fact that the pre-service teachers gained experience and developed their problem-solving skills in the process of the robotics design (Robinson, 2005). The highest levels of motivation and enjoyment were revealed when the robots had more features (multiple sensors and movements). Since the design process for robots takes time and some problems may occur during the process, group work is convenient for robotics activities (Liu, Lin, & Chang, 2010; Mitnik, Nussbaum & Recabarren, 2009). Teamwork makes it easier to overcome difficulties, and so the learning process becomes more enjoyable (Denton, 1994; Gomez et al., 2010). In the literature, teamwork is preferred in robotics activities (Atmatzidou & Demetriadis, 2012; Liu, Lin & Chang, 2010). In accord with the literature (Kim et al., 2015; Nugent et al., 2010), the pre-service teachers were satisfied with the course and they had a high level of motivation and enjoyment during the course. These kinds of enjoyable and motivational activities lead to an active learning environment (Harel & Papert, 1991). Regarding relationships among SMECC, strong relationships were found among satisfaction, motivation, and enjoyment. As stated in the literature, ER activities provide motivation and enjoyment to the learning process (Petre & Price, 2004). Therefore, participants' satisfaction may also be high level. Negative relationships have been revealed among challenge, satisfaction, and motivation. Even though the pre-service teachers had difficulties in some activities, this did not influence their satisfaction and motivation. Developing a product after solving the difficulties leads to a high level of motivation (Petre & Price, 2004).

Pre-service Teachers' Learning Experiences

The pre-service teachers' learning experiences have been categorized under three main areas: behavioral, cognitive and emotional.

Behavioral Experiences

The behavioral experiences during the activities were categorized as challenges with material and challenges with process. The stated issues were wrong assembly, connecting to the wrong port, small parts, and disassembly, respectively in challenges with materials category. These issues may be explained by the fact that the pre-service teachers were careless or hasty in the assembly process. On the other hand, these challenges with the materials caused challenges with the process such as correcting mistakes, distractibility, and working in a group. That is, the challenges encountered during the robotics activities are closely related to each other. Distractibility may cause a wrong assembly issue, and when the participants detected this problem, they had to correct the mistake. Sometimes they had to go back to the beginning steps to discover the mistake. However, this kind of challenge can lead to an improvement in engineering design skills due to the assembling process (Barak & Zadok, 2009).

Cognitive Experiences

Cognitive experiences during the activities were categorized as attention factors and working strategies. The attention factors were considered along with both positive and negative influences. While some participants claimed working in a group caused distractions, others claimed that this improved attention. As stated in the literature, a number of factors may moderate the impact of collaboration on student learning, including student characteristics, group composition, and task characteristics (Lai, 2011). This course provided a project-based learning environment which included collaborative activities. Most of the participants were not used to developing a product in collaboration. Therefore, they may have discovered advantages and disadvantages from working as a group in the course. The advantages and disadvantages of working as a group are referred to in the literature as well (Beebe & Masterson, 2003; Davis, 1993; Elgort, Smith, & Toland, 2008). In addition, the period of time, enjoyment, flow, and short breaks in the course were considered as factors that influenced attention. Most of the participants preferred working in a group. On the other hand, some of the participants preferred either group or individual work based on the particular type of activity. In accord with the literature, working in a group provides many advantages such as collaboration, multiple perspectives, creativity, enjoyment, and motivation (Lai, 2011). But some pre-service teachers stated that the process would be faster and more creative if they worked individually and could control everything by themselves (Beebe & Masterson, 2003).

Emotional Experiences

Emotional experiences during the activities were categorized as perceived course outcomes and perceived enjoyment. The most mentioned outcome was learning to teach robotics. Because they gained pedagogical and technical knowledge, preservice teachers in these kinds of courses learn to teach robotics to their students and to integrate robotics into other lessons (Kim at al., 2015). Moreover, ER activities allow for the development of STEM skills, programming skills, imagination, and the act of developing a product, all of which require analytical thinking, multiple perspectives, and three-dimensional thinking (Eguchi, 2014; Mauch, 2001; Nugent et al., 2012). Regarding perceived enjoyment on the part of the pre-service teachers in robotics activities, most participants particularly enjoyed the Puppy Robot (Activity 8) because it had more features (multiple sensors and movements).

Pre-service Teachers' Engagement during Robotics Activities

The pre-service teachers' engagements have been categorized under four main areas: behavioral, cognitive, emotional and agentic.

Behavioral Engagement

Regarding the behavioral engagement of the participants, it was observed that the groups overcame the challenges of a high level of collaboration and they accelerated the process by sharing the work. As stated in the literature, this is one of the advantages of collaborative work in robotics activities (Cheng, Huang & Huang, 2013; Çayır, 2010; Kapa, 1999; Liu, Lin, & Chang, 2010). When competition among the groups is promoted, students adopt corresponding performance goals (Walker & Greene, 2009). On the other hand, even though Cheng, Huang, and Huang (2013) have stated that gender does not play a role in robotics education, it was observed in this study that male pre-service teachers had a lower level of behavioral engagement and they completed the activities in a longer time than did the groups consisting of female pre-service teachers. In accord with this finding, Kim et al. (2015) stated that the female students needed less help in the ER activities. However, contrary to this finding, Voyles, Fossum, and Haller (2008) found that girls were less able and needed more assistance than boys in challenging tasks. Another important finding is that the female pre-service teachers generally completed the activities in a shorter time. Contrary to this finding, Sullivan and Bers (2013) found that boys scored significantly higher than girls only in properly attaching robotics materials. This result may be related to participants' prior experience with Lego toys. Also, it can be deduced that female pre-service teachers may be more inclined to such activities in terms of behavioral engagement.

Cognitive Engagement

It was observed that the groups all put in a high level of cognitive effort in order to complete the robotics activities in the first few weeks. However, this cognitive effort was focused on finding different strategies to accelerate the assembly process in the following weeks. Participants can develop different cognitive strategies to accelerate the process as they gain more experience in such activities, which may support the creative thinking of the students (Bilotta, Gabriele, Servidio, & Tavernise, 2009). As Sweller indicated (2010), worked examples, which show learners the worked-out solution steps required to reach the goal, allow novice students to create a cognitive structure for complex subjects and they facilitate learning and transfer of knowledge. In addition, as the weeks progressed, it was observed that the pre-service teachers had less cognitive difficulty and performed better. It is thought that carrying out the robotics activities with the help of a guidebook, which was designed in accordance with the segmenting principle, decreased the cognitive load. Thus, the cognitive load sourced by the complexity of the process can be optimized (Clark et al., 2006; Mayer, 2005).

Emotional Engagement

The participants seemed to enjoy and flow during the robotics activities. Similar findings have been reported in the literature (Alimisis, 2013; Chun-Wang, I-Chun, Ling, & Nian-Shing, 2011; Eguchi, 2010; Moundridou, & Kalinoglou, 2008; Kim et al., 2015). The participants shared their feelings excitedly with their instructor and friends after completing the robot and some of them took pictures of the robots to share on social media. This can be explained by the fact that they were digital natives and they wanted to be liked by their friends. This finding is consistent with the social media behaviors of digital natives (Brooke, 2010). Participants had a high level of emotional engagement. According to the findings, using different parts (motors, gears, sensors, etc.) and features (sound detection, obstacle detection, etc.) in the design process of the robots influenced the emotional engagement of the pre-service teachers. For example, when the robot moved and worked properly, the participants seemed happy; otherwise, they seemed nervous. This finding may be because they perceived the process as a game. Another important finding is that the female participants expressed their feelings in a more open way during the robotics activities. In accord with this finding, Kim et al. (2015) stated that female students were more interactive and communicative within the group.

Agentic Engagement

The groups had problems due to assembling parts in the wrong way, and they asked for help from the instructor in the beginning weeks of the course. However, in the following weeks, the groups could solve such problems with teamwork without the help of the instructor. The collaborative activities were designed in accordance with the constructivist learning approach. The teacher played a guidance role and the students were agentically active. When the pre-service teachers encountered problems, the instructor used a demonstration method to help them solve problems. Indeed, the role of the teacher within the classroom and his/her instructional approach is very important in helping students become agentically active (Beisser, 2005; Lindh & Holgersson, 2007).

Conclusion

The findings of this study, which examine in detail the robotics learning process of pre-service teachers, are crucial in terms of designing similar courses in TTIs. Using qualitative and quantitative research methods strengthened the findings of the study. However, the study had some limitations such as the limited number of participants and the focus on only the robotics design process rather than robotics programming. Based on the results, this study provides the following suggestions. Working in groups increases collaboration within the group, and work sharing accelerates the assembly process. However, some of the participants who were used to working individually stated that with an individual working process, they could be faster and more creative as they could control the process better in some activities. Therefore, in the following weeks, participants who prefer working in groups or individually could be identified and the experience of working individually could be presented to the participants, at least for some activities. Moreover, differences in psychomotor skills and comprehension levels of group members may reveal problems within the group. For this reason, it would be better to choose group members in a way that these differences are balanced.

In addition, it has been observed that developing interactive robots by making use of sensors increased the enjoyment and motivation. So it might be more appropriate to start the design robotics activities with sensors earlier. Even though pre-service teachers had challenges at the beginning in recognizing the parts of the RD kit and assembling them, these difficulties disappeared as they gained experience and developed their problem-solving skills. Furthermore, robotics activities could turn into a competition among the groups to finish assembling the robots quickly. It has been observed that this competitive atmosphere may cause panic and stress for some participants. For this reason, some precautions could be taken to remind the participants that it is not important to finish quickly but rather to construct the robot properly. In addition, robotics activities require a mental effort. Even small distractions may cause a wrong assembly of parts. In this case, identifying the mistake and redesigning the robot starting from the wrong assembly step may be required. But this situation may negatively influence the participants' motivation. For this reason, it is essential to choose an appropriate period of time and length of class for participants to stay mentally active.

This study has shown that the most motivating point in this course on pre-service teachers is that they can learn the science of robotics so that they can teach their own students in the future. For this reason, theoretical insights into robotics science, pedagogical approaches toward teaching robotics, and integration of ER into the different fields should be provided in detail in ER courses. ER kits containing guide books such as Robotis Dream could be preferred throughout the ER courses. These kits ease the process as they systematize the bottom up procedure teaching. Creative Thinking Spiral Model has been utilized in the phase of Pre-service teachers' own robot design. The provision of such trainings focusing on the multiplicity of perspectives and creative thinking could enable them to design robotic education appropriate to their own target audience in the future. In the future, studies with a larger number of participants from various fields could be conducted. These studies should focus on algorithms and programming. The current study was designed for pre-service teachers from different fields. Specific courses could be designed for different education fields (pre-school, elementary, math, science, etc.) through collaborating with other departments in the TTIs. In addition, longitudinal studies could be conducted to evaluate pre-service teachers' use of ER in their future classrooms.

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Appendix A
Post Activity Survey

Name Surname: **Group:**

Activity Name: ……………………………………………………………..
Activity Time: ……………………………………………………………...
Date: …...………………………………………….................................

How satisfying was the activity?

Very little	Little	Neutral	High	Very High

How motivated did you feel during the activity?

Very little	Little	Neutral	High	Very High

How enjoyable was the activity?

Very little	Little	Neutral	High	Very High

How challenging was the activity?

Very little	Little	Neutral	High	Very High

How much did you collaborate with your teammates?

Very little	Little	Neutral	High	Very High

Write yout thoughts about the activity (What did you like, what did you learned, challenges etc.):

Appendix B

Observation Form

Behavioral Engagement	Evaluation			Explanation
	Yes	Partially	No	
Following instructions on the guidebook				
Following instructor's instructions				
Assembling-dissembling the bricks properly				
Finding proper components and classify them				
Asking questions to instructor/friends				

Emotional Engagement	Evaluation			Explanation
	Yes	Partially	No	
Expressing feelings about the activity				
Sharing emotions with friends and instructor				

Cognitive Engagement	Evaluation			Explanation
	Yes	Partially	No	
Reviewing the activity book				
Examining and classifying educational robotics parts				
Creating accelerating solutions				
Expressing the complexity of the activity				
Getting help from friends / solving problems without getting help				

Agentic Engagement	Evaluation			Explanation
	Yes	Partially	No	
Asking questions to the instructor, expressing situations of interest				
Endeavoring to solve problems				
Trying and correcting mistakes				

Appendix C
Interview Questions

COURSE PROCESS

1. What were the most enjoyable/boring and hardest/easiest activities? Why?
2. What were the hardest and easiest activities? Why?
3. What challenges did you encounter in the course of doing robot activities? What were you doing when you faced challenges? How did you overcome the challenges?
4. Have you ever been distracted in the process? What were you doing in these situations?
5. How did you feel when you were working on robotics activities?
6. What were the situations in which you didn't like the robot activities? Can you explain?
7. Do you prefer to work individual or in a group when designing a robot? Why? What were the benefits of working with the group during the course?

PROJECT

8. Did all the team members work equally in the process? Which methods did you use? How was your communication with team members? Can you explain this process?
9. How did you create your project idea? Did you link it with real-life problems? How?
10. What are the benefits of working with a group?
11. Do you prefer individual or group work when developing a new robot? Why?

GENERAL EVALUATION

12. Do you think this course is useful for you? Why?
13. How would you consider using what you learned in this lesson when you became teacher in the future? Can you explain with examples? How can you relate it with your own domain?
14. Do you think it is necessary for teachers to know robotics design and programming? Why? Would you recommend this course to others? Why?
15. How were your thoughts before starting this course? What are your thoughts now? How do you see yourself in robotics design and programming?