DESIGN OF COLLABORATIVE PROBLEM-SOLVING ACTIVITIES WITH EDUCATIONAL ROBOTS FOR MIDDLE SCHOOL STUDENTS

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

DESIGN OF COLLABORATIVE PROBLEM-SOLVING ACTIVITIES WITH EDUCATIONAL ROBOTS FOR MIDDLE SCHOOL STUDENTS

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Doctor of Philosophy, Computer Education and Instructional Technology
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The purpose of this study was to explore the design of collaborative problem-solving activities in order to solve ill-structured problems in science with educational robots for middle school students. In conjunction with this purpose, a formative research design was followed to investigate the development and implementation process of ill-structured problem-solving activities. Accordingly, problem-solving activities were developed by the help of faculty members in science education and instructional technology departments and practitioners in middle schools. The objectives were chosen at the 5th grade level for Information Technologies and Software (ITS) and Science Courses. Subjects were associated with the problem-solving and programming units for Information Technologies and Software (ITS) Course. They were also related to physical events, creatures, and life units of the Science Course. As a result, four activities namely Robot Factory, Lifeguard Robot, Savior Robot and Scavenger Robot were developed prior to the implementation process. Implementation phase was carried out over two cycles in two different public schools. Several modifications were made to the activities during these cycles. Furthermore, research questions were explored with the opinions of teacher and middle school students (totally 24 5^{th} graders in the first cycle and 51 6^{th} graders in the second cycle) during the implementation process. Data were collected through semi-structured interviews, activity sheets, reflection diaries, and tests on the related subject of the activities.

Keywords: Problem Solving, Ill-structured Problems, Educational Robots,
Formative Research

ÖZ

ORTAOKUL ÖĞRENCİLERİ İÇİN EĞİTSEL ROBOTLARIN KULLANILDIĞI İŞBİRLİKLİ PROBLEM ÇÖZME ETKİNLİKLERİNİN TASARIMI

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Bu çalışmanın amacı, eğitsel robotlar ile fen bilgisi alanındaki yapılandırılmamış problemleri çözmek için ortaokul öğrencilerine yönelik iş birliğine dayalı problem çözme etkinliklerinin tasarımını incelemektir. Bu amaç doğrultusunda, yapılandırılmamış problem çözme etkinliklerinin geliştirilme ve uygulama süreçleri biçimlendirici araştırma tasarımı kullanılarak takip edilmiştir. Özel olarak bu etkinlikler fen eğitimi ve öğretim teknolojileri bölümlerindeki uzmanlar ve ortaokul düzeyinde görev yapan öğretmenlerin yardımlarıyla geliştirilmiştir. Etkinlikler için kazanımlar 5. sınıf düzeyindeki Bilişim Teknolojileri ve Yazılım (BTY) dersi ile Fen Bilimleri dersinden alınmıştır. Bu bağlamda Bilişim Teknolojileri ve Yazılım (BTY) dersi için etkinlik konuları problem çözme ve programlama üniteleridir. Ayrıca, bu konular Fen Bilimleri dersindeki fiziksel olaylar, canlılar ve yaşam konu alanları ile bağlantılıdır. Sonuç olarak, uygulama süreci öncesinde Robot Fabrikası, Cankurtaran Robot, Kurtarıcı Robot ve Çöpçü Robot olmak üzere dört etkinlik geliştirilmiştir. Oluşturulan etkinliklerin uygulama süreci farklı devlet okullarında iki farklı döngü halinde gerçekleştirilmiştir. Bu döngüler sırasında etkinlikler ve uygulama süreci üzerinde çeşitli değişiklikler yapılmıştır. Ayrıca uygulama sürecinde öğretmen ve ortaokul öğrencilerinin (birinci aşamada 24 5. sınıf, ikinci aşamada 51 6. sınıf) görüşleri doğrultusunda araştırma sorularına cevap aranmıştır. Araştırmanın verileri katılımcılardan yarı yapılandırılmış görüşmeler, etkinlik yaprakları, yansıtıcı günlükler ve etkinlik konuları ile ilgili sınavlar aracılığıyla toplanmıştır.

Anahtar Kelimeler: Problem Çözme, Yapılandırılmamış Problemler, Eğitsel Robotlar, Biçimlendirici Araştıma

To a short life like hugging a tree

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(Şura and Ruveyda) and nephews (Enes and Fatih) was sufficient to encourage me during my journey. On my side, I'm incredibly lucky to have you all.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS

A1: Activity-1 (Robot Factory)

A2: Activity-2 (Lifeguard Robot)

A3: Activity-3 (Savior Robot)

A4: Activity-4 (Scavenger Robot)

ACS: Analysis of Current Status

ER: Educational Robots

CPS: Collaborative Problem-Solving

PS: Problem-Solving

CHAPTER 1

INTRODUCTION

This chapter provides a general background to the study, starting with a brief review of the literature on educational robots, definition of “problem-solving” and the concept’s applications in learning environments. The current state of research is also presented on the subject. The significance of the study – animated by its purpose and its research questions – is then explained via its situation on the basis of previous research. Finally, the definitions of key terms used in the current study are also provided at the end of the chapter.

Robots, the central feature of the a rapidly growing field of robotics in educational environments, sometimes act as content-providing tools, while others serve as learning materials that allow learners to operate them directly (Park, Kim, Oh, Jang & Lim, 2015). In the latter case, students can convert themselves from a passive receiver to an active learner by developing a number of mental skills and new knowledge based on a constructivist learning approach (Atmatzidou & Demetriadis, 2014). This innovative feature has made robots popular in informal education in the form of extracurricular programs (Polishuk et al., 2012). One of the main advantages of holding informal training sessions with educational robots is that they are short-term and require both minimum curriculum design and minimum required training for teaching staff, as robot experts are there to assist. Nonetheless, informal sessions are usually one-off and thus their longitudinal impact can be questioned (Mubin, Stevens, Shahid, Mahmud, & Dong, 2013b). In addition, most of these sessions have high participation costs (Balogh & Petrovič, 2020) and organizational difficulties brought on by the fact that they have high number of participants (Lima & Custódio, 2005).

Educational robots are an all-in-one technological learning tool that encourages the future success of our students and is expected to be increasingly integrated into the curriculum of the schools (Eguchi, 2014b). The characteristics of tangibility and excitement make them an inseparable part of the classroom (Karim, Lemaigman & Mondala, 2015). The idea of incorporating robotics into the learning process is no longer a novelty, but there is still a question of how it can be used to promote the development of certain skills and which pedagogical principles should be taken into account (Daniela & Lytras, 2018 as cited in Daniela, 2019).

Due to the strong emphasis on standardized tests and the demand to meet the government's academic standards, it is very difficult for teachers to include robotics in their school curriculum (Eguchi, 2017). Several attempts at their inclusion have led to robotics being developed as a separate subject, as opposed to a supporting element to the existing packed curricula, which is another difficulty for teachers (Ching et al., 2019). Koç and Şenol (2012) suggested the investigation of robotic applications through a combination of the science and technology disciplines in education. Within this new framework, they can change students' perceptions and understandings by making it possible to access different types of information when used as a complementary addition to conventional science teaching. Therefore, designing a study to extract design requirements in collaboration with the content of these disciplines can be crucial as well as beneficial. The design of such an environment may offer multi-faceted challenges, so there are a number of issues to be explored from an educational perspective (Panayiotou & Eteokleous-Grigoriou, 2017).

The literature indicates the necessity of applying unique learning methods to the use of educational robots established and connected to the general curricula in schools (Kubilinskiene, Zilinskiene, Dagiene, & Sinkevicius, 2017). PBL puts students in an active role in which they can cope with authentic tasks and learn through designing robots and problem-solving by using these educational tools. This method has several advantages over traditional education, but designers are increasingly aware of the difficulties and limitations of applying it in the regular school environment.

Therefore, exploring the potentials of constructivist problem-solving environments enriched with educational robots needs careful designs of content and methodology (Barak & Assal, 2018).

Atmatzidou, Demetriadis and Nika (2018) argue that a guided framework for problem-solving with educational robots maximizes the learning benefits of these powerful learning environments. In these environments, students should work in groups, in which members have assigned roles and collaborate with others. Detailed instructions on the process can be provided through worksheets covering special problem-solving strategies. In addition, the workload of the students should be reduced through fading guidance during the problem-solving process. This guidance, in turn, may be based on the general steps (understand the problem and plan, implement, and evaluate the solution) of the problem-solving process of well-structured problems. However, according to Jonassen (2004), different intellectual skills are needed to solve ill-structured problems than well-structured ones. The methods of teaching well-structured problem solving cannot, therefore, be used effectively to teach ill-structured problems. It seems likely that the solution of some very ill-structured problems simply cannot be taught by anyone else. Such solutions must be experienced by the problem solver through the execution of an ill-structured problem solving process.

A limited number of guidelines have been introduced in the literature. In one of them, Williams et al. (2007) outlined six principles for developing and implementing robotic programs. The program was conducted in a robotic camp which was designed for middle school students and consisted of hands-on group activities that provided experiments with physics concepts. Üçgül (2012) conducted a further study to unveil the design principles for educational robotic training camps. In that study, two robotic camps were organized with elementary school students. Both studies have contributed to the literature by investigating robotic activities in non-formal educational settings.

On the other hand, Kamga et al. (2017) introduced the design requirements for robotic education activities that promote a collaborative problem-solving approach when integrated into a typical school curriculum. The findings of the study were only based on the literature review. These design requirements should therefore be confirmed in the context of the intervention of problem solving activities with educational robots. Gürkanlı (2018) also looked at the design requirements of educational robotics in a school environment from the perspective of 15 teachers. It was interesting that only one of the instructors involved (with two years' experience) used these tools in curricula. The rest of the instructors all reported that they used robots as extracurricular activities. All instructors who participated were also working in private schools, which was another limitation of the study. The researcher expressed that there may be different needs in the context of government schools. In addition, information provided by only instructors may be biased since there is also a need to collect the opinions of the students involved in the real context of the activities.

1.1 Background of the Study

In order to enhance the benefits of education for students, the aim should be to involve them in a meaningful learning experience. Constructivist learning environments focus on integrated curriculum in a number of fields and use materials in such a way that students are actively involved in their meaning-making. The goal of a constructivist activity is therefore to provide a rich experience that encourages students to learn with a great deal of activity, social interaction, and authenticity (Schunk, 2012). The major question of how to prepare students in these learning environments, however, lies at the heart of the problem of bringing knowledge and skills acquired in the classroom to the rest of the students' lives (Bruner, 1999). Problem-solving activities can be the most meaningful kind in formal educational settings as they involve tasks requiring active, constructive, and intentional cooperation. As a result, the demands of the non-school world (everyday life, business, hobbies) could be met by training competent problem solvers in schools (Jonassen, Howland, Moore, & Marra, 2003).

According to Jonassen (2010), problem-solving activities are the most authentic and relevant learning activities for students. Knowledge built up in these activities is better understood, maintained, and more flexible, since the construction of meaning here requires the learner's intention to understand the context. In addition, the information that is used for tasks that are not authentic can easily be forgotten, which reduces the effectiveness of the information and learning. Therefore, such inauthentic tasks are time consuming for the learner. On the other hand, problem-solving in authentic contexts make the most effective use of the time available. The primary objective in an educational context (formal or informal) should therefore be to engage and encourage learning to solve authentic problems. With this general goal, the schools from kindergarten through graduate levels have a mission to serve content to the students with an explicit purpose of solving problems, which makes the content more meaningful for them (Jonassen, 2004).

Problem-solving, identified as one of the important 21st century skills (Blanchard, Freiman, & Lirrete-pitre, 2010; Alimisis, 2013; Ma & Williams, 2013; Eguchi, 2016; Theodoropoulos, Antoniou, & Lepouras, 2017; Kamga, Romero, Komis, & Mirsili, 2017; Jaleniauskienė & Jucevičienė, 2018), is expected to be mastered by today's learners – future citizens – to succeed in a rapidly changing world (Delisle, 1997). They must be supported with educational settings that will enhance problem-solving skills outside the classroom in order for them to be equipped for successful life in modern times. For their problem-solving, in turn, to be effective in real-world situations, it is critical that problem-solving activities in the classroom be linked to real-world contexts (Castledine & Chalmers, 2011).

However, problems in the learning environments and in the real world tend to be different, as do the strategies and methods to solve them. The most general conceptualization of the difference between the problems is a classification created according to their structures. The problems encountered in formal educational contexts are commonly well-structured problems. Briefly, the representation of these problems includes all the information necessary for the problem solver to solve them. Beyond this, solving such problems requires only a limited number of rules and principles that are applied according to previously known ways. As a result, a convergent, standard answer will be reached at the end of the problem-solving process. On the other hand, the ill-structured problems of everyday life involve one or more unknown problem elements in various content domains. These naturally interdisciplinary problems have conflicting goals and multiple solution methods and paths. These uncertainties require learners to make judgments and express opinions on the problem itself (Jonassen, 2010). As they are different in nature, the processes in both types of problem-solving are not the same, therefore the methods employed to teach students to solve well-structured problems cannot be effectively applied to ill-structured problems. They must be experienced in practice using specific knowledge and skills (Jonassen, 2004).

Even if the frequently encountered challenges in everyday life are ill-structured problems, as opposed to their well-structured counterparts, such problems still need to be a part of the educational repertoire to prepare students for future life (Daniels, Carbone, Hauer, & Moore, 2007). For instructional use, the ill-structured problem-solving process typically includes (1) problem representation, (2) solution generation, (3) making justifications, and (4) monitoring and evaluation steps (Xun & Land, 2004). In a more detailed model (Jonassen, 1997), the process begins with the construction of the problem space. The problem solver must settle on the existence of the problem statement since it may not be explicit in the context. Once it exists, this problem space can be improved with the possible causes and contextual constraints of the problem. Then, this problem space is expanded to locate the alternative viewpoints and opinions to find the most relevant and useful problem scheme. An iterative argumentation and reasoning mechanism to support the selection of a particular cause and solution will be there since it is very possible to have widely different and alternative solutions. In order to determine the feasibility of these potential solutions, the problem-solver needs to decide whether to proceed with the implementation of the solution. After the solution has been applied, it is necessary to monitor the solution in order to adapt it to other problems or to decide on a solution adjustment.

Problem-based learning (PBL) environments have become more and more popular in educational settings since they provide particularly appropriate programs for solving ill-structured problems. According to Tan (2003), an ill-structured problem, which typically originates from the real world or is in some way highly authentic, constitutes the starting point of learning in PBL approaches. The teacher using PBL should form this trigger problem as one that is developmentally appropriate for the students, grounded in their experience, curriculum-based, and able to accommodate a variety of teaching and learning strategies (Delisle, 1997). The student should then be highly responsible for the learning, undertaken within a collaborative or cooperative pedagogical framework which includes elements of group work. The interdisciplinarity of the problem is important in this collaborative environment as the problem comes from the real world and it directs learning (Ryberg, 2019). These instructional features of PBL offer an environment where social interactions are crucial for the co-construction of artifacts and knowledge building among students. With this major focus on social learning, PBL is a groundbreaking pedagogy to identify and integrate social elements of learning processes. Therefore, PBL will continue to evolve to achieve the goal of training capable problem solvers for the benefit of society (Hung, Moallem, & Dabbagh, 2019).

The designers of ill-structured problem-solving activities need to focus on three key integrated components of these constructivist learning environments. One of these components, the context of the problem, refers to the description of all contextual factors surrounding the problem. These factors include the physical, socio-cultural, and organizational climate, the time and location of the phenomena, and the resources as well as key players such as stakeholders or performers in the problem. In addition, the representation of the problem refers to stories or scenarios of the problem, which must be interesting, attractive, and engaging to the problem solver. Among them, authentic representations support the performance of specific real-world tasks by providing replication of the context structure. These representations give the problem solver a chance to engage in a relevant and meaningful challenge. Problem manipulation space is a critical feature of meaningful learning here since the learner needs to be active to manipulate something (construct a product, manipulate parameters, and make decisions) and affect the environment during the problem-solving process. These manipulation spaces allow students to test their decisions on the solution by giving feedback in their actions. They must therefore be sensitive, realistic, and informative in nature (Jonassen, 2013).

In this way, educational robots were considered the most suitable tool in the current study for manipulating the problem-solving activities. According to Oddie, Hazlewood, Blakeway and Whitfield (2010), problem-solving with educational robots allows the students to learn, collaborate, and explore in a constructivist environment. Specifically, it motivates students to exceed the tasks set for the course because they wanted to formulate difficulties to explore the solution. During this exploration, visual and tangible outputs of their solutions are usually influenced by real-world factors since these tools give them immediate feedback and help them take control of learning, rather than looking for solutions from the instructors. Catlin (2017) argues that educational robots provide "excellent opportunities to engage students in problem solving tasks" (p.144). These tools can be used in learning environments to experience different complex issues, from small-scale challenges to projects. Designing better problem-solving activities will therefore help students learn more and faster, gain deeper understandings, remember longer, and enjoy their learning experience (p.146).

Komis, Romero and Misirli (2017) have introduced a taxonomy of learner involvement in the process of knowledge building through educational robotic activities. In this taxonomy, different types of activities are organized into five levels: (1) passive exposure to robotics (without manipulation), (2) discussion or debate on robotics (without manipulation), (3) individual or collaborative step-by-step robotics (procedural), (4) engineering-oriented robotics (individual or collaborative), and (5) co-creative project-oriented robotics in order to solve a realistic challenge. The first two levels do not refer to creative problem-solving processes as they introduce the use of tools (ERs) without manipulating them. However, they are also crucial pre-steps in terms of the critical and epistemological questionings about these tools that take place prior to other activities. Procedural ER activities allow students to follow step-by-step instructions that teachers or tutorials prescribe for themselves. Students should closely follow the stages of construction, programming, and implementation in order to achieve a predefined result that does not allow for a change during the solution process. Students face a certain level of problem-solving challenge that makes the co-creative resolution process entertaining during engineering-oriented activities. However, the context of the activity is very close to a standard procedural activity. On the other hand, students are encouraged to solve realistic problems in co-creative project-oriented activities. Developing creative solutions to real problems is expected in connection with the design and programming of the robots in this level. In addition, an appropriate teaching plan should incorporate the other levels in order to develop pre-requisite programming competencies prior to this level of activity.

1.2 Problem Statement

For a while now, the use of robots in education has been recognized as a subject. The need to move them into school environments has been indicated by the extracurricular applications of these tools. This transport may be made as a separate subject as well as the use of them as supporting elements to the packed curriculum. In both cases, the aim of the integration is to contribute to the understandings of the learners in a number of ways. Additionally, this integration can also be made to cover several fields of education. Thus, learning practice becomes an interdisciplinary structure so that learning is not limited to the content of a lecture. Conducting a study addressing design issues of activities with the integration of the robots into the curriculum in an interdisciplinary manner, as is the focus of the current study, therefore can be crucial for the investigation.

Furthermore, it is necessary to establish the application of unique learning methods to link the use of robots to the general curriculum. For an effective link, the methodology could be constructivist problem-solving approaches enriched with educational robots. Ill-structured problem-solving can provide this link with a collaborative and meaningful learning experience for students in the PBL environment. This meaningful learning experience can be used to develop guidelines for the implementation of activities. Therefore, the design issues of such a learning environment should be carefully studied in order to maximize the learning benefits of students. However, guidelines for such activities were the scope of a limited number of studies in the literature. There is therefore a need to conduct research on design issues for collaborative problem-solving activities with educational robots in order to make a contribution to the future instructional design theory.

1.3 Purpose of the Study

The purpose of the study is to explore issues in designing collaborative problem-solving activities involving educational robots to solve ill-structured problems developed according to the content of middle school Information Technologies and Software (ITS) and Science Courses. Specifically, the development of ill-structured problem-solving activities and middle school students' problem-solving processes in these activities will be examined in detail. In the first place, the development process of these activities will be elaborated on as a guide for their final design. The opinions of students and instructors, based on their experiences in the process of implementing the activities, will be determined in order to unveil the enablers, challenges, and characteristics of the problem-solving activities. Finally, a guideline for activities will be established to assist practitioners and instructional designers with similar activities in the future. In this regard, the current study aims to shed light on the effective and efficient use of problem-solving activities with educational robots in middle schools, to contribute to the corresponding literature, and to offer suggestions on the use of these activities.

1.4 Research Questions

In conjunction with the purpose of the study, the main question addressed during the research is: "How should problem-solving activities for middle school students be designed to solve ill-structured problems in science using educational robots?"

The sub-questions of the research are:

1) What are the enablers and challenges of problem-solving activities designed for middle school students to solve ill-structured problems in science using educational robots?

2) What are the characteristics of problem-solving activities designed for middle school students to solve ill-structured problems in science using educational robots?

3) What are the guidelines of problem-solving activities designed for middle school students to solve ill-structured problems in science using educational robots?

1.5 Significance of the Study

The proposed problem-solving activities were expected to serve as a meaningful learning experience for middle school students. In detail, each activity began with an uncertainty (ill-structured problem) as a starting point for the PBL environment. The students then followed a problem-solving process, composed in consultation with the corresponding literature, in order to find a solution at the end of the activity. All students, simply, were expected to experience an ill-structured problem-solving process. The related literature has indicated that the learning environment in schools rarely encompasses ill-structured problems that are authentic and close to real life in nature. Accordingly, the students' experience in these activities is therefore crucial to contribute to the literature aimed at addressing ill-structured problems in education.

The literature on problem-solving with educational robots has shown that they are commonly used in extracurricular programs as a part of non-formal educational settings. There are however, several unique difficulties in these environments, such as problems with the training of teaching staff, high costs of participation, and limited number of admissions. On the other hand, the contributions of these programs include promising outcomes for students such as skill development, a high level of motivation, and an improvement in academic achievement. These hopeful outcomes make such attempts inevitable for school curricular integration. However, the reality of differences between learning environments speaks to the need to examine implementations in the school environment separately. This research, which aims to design problem-solving activities through the use of educational robots with a combination of two course content (ITS and Science) in middle schools, may guide instructional designers and practitioners who wants to use such activities in school environments.

The students' ill-structured problem-solving process was the main focus of the proposed activities in the current study. In detail, the framework and related literature have been carefully investigated in the development process of these activities. In addition, field experts' and practitioners' opinions have been consulted on an ongoing basis to properly design constructivist problem-solving environments enriched with educational robots. The design and development process of the activities was reflected in the findings part of the report. In addition, these findings were elaborated in the discussion part of the study to provide insights to instructional designers who will develop similar activities.

The first two sub-research questions of the current study were addressing the enablers, challenges, and characteristics of the activities in which middle school students solve the ill-structured problems in science through the use of educational robots. The data collected from students and teachers who participated in the implementation process of these activities constituted the findings that addressed these two questions. As in the constructivist approach, these findings have been delivered from the experience of the activity participants. These findings may therefore shed light on future research that investigates the implementation process of similar problem-solving activities. In addition, some of the findings were specifically related to the tools (robots) used in the current study, and are therefore expected to be useful for producers of tools intended for educational use.

Several guidelines for the implementation of these tools in educational settings have been found in the literature. However, most of them were based on reviews of related literature or interventions in extracurricular programs. Furthermore, a limited number of existing guidelines fit for the integration of these tools into activities in which students work on ill-structured problems. As a result, specific guidelines for implementing activities in which middle school students solve ill-structured science problems with educational robots were addressed with a sub-research question in this study. These guidelines could contribute to the development of an instructional design theory for interdisciplinary collaborative problem-solving activities in which middle school students solve ill-structured science problems with educational robots.

1.6 Limitations

There were some limitations in the current study. In the first place, the participants in the research were different in the development of the activities and the implementation phases. At the beginning of the development process, three instructors were interviewed for analysis of the current status as a decision-making mean for problem-solving activities. Then, four science teachers who had already experienced educational robots were interviewed for their suggestions on activities. The draft version of the activities was prepared at the meeting of the focus group which includes the researcher himself, expert, and teachers (four participants in total). Finally, the activity scenarios were evaluated by four experts in the field of science and instructional technology to take the final form of the activities.

During the implementation process, a total of 75 middle school students participated in the activities. In the first cycle of the implementation, 24 fifth grade students from a public school participated in the study. For the second cycle, participants were 51 sixth grade students from a public vocational school. Additionally, the teacher of these classes during these implementations was an important data source for the current study. Therefore, the findings of the study were limited to the opinions and experiences of these participants, which differed in the process of development and implementation of the problem-solving activities.

Another potential limitation was regarding data collection techniques, since none of them was a direct method of measurement in the current study. In detail, several tools have been used to collect data from the participants in the current study. The majority of the data sources were gathered from meetings with the participants. These meetings were conducted as semi-structured interviews and the questions asked to the participants were based on the corresponding literature. The findings of the current study were therefore limited to the answers to these interview questions. In addition, these findings were limited to data collection tools such as text-supported drawings, a student reflection paper, group activity sheets, and two pre-and post-tests on the related subject of the activities, all of which were used as supporting data sources.

A further limitation of the study was the use of observations as supporting data for the implementation of the activities. The observation form was developed prior to the implementation process, but as the researcher was very active, it was not possible to fill out the form during the activities. Therefore, the observation forms were not used effectively. Instead, only the observation data remembered were used as supporting data, which was one of the limitations of the current study.

1.7 Delimitations

The problem-solving activities in the current study have been developed in line with the content of the ITS and the Science Courses. The objectives for both courses were chosen at the 5th grade level. Subjects were associated with a problem-solving and programming unit for the ITS Course and related to physical events, creatures, and life units in the Science Course.

The activities were carried out at the Gültepe Middle School, which was the actual context of the first cycle activities, which took place in the 2017-2018 spring semester. The school selected for the second cycle was Cahit Zarifoğlu Imam Hatip Secondary School in the 2018-2019 fall semester. The results of the current study therefore were limited by both the contexts of these schools and the selected subjects for problem-solving activities.

1.8 Definitions of Terms

Ill-structured Problem: Ill-structured problems are types of problems that most frequently occur in daily and professional practice. These issues are not necessarily consistent with the content domains being studied, so their solutions are neither predictable nor convergent. These interdisciplinary problems cannot be solved by applying concepts and principles from a single domain (Jonassen, 2004).

Educational Robotics: Educational robots are tools which help to enhance the learning experience of students "through hands-on mind-on learning". Most importantly, educational robotics provide a fun and exciting environment for learning because of its practical nature and technological integration (Eguchi, 2017, p.3). More broadly, educational robotics is "a field of study that aims to improve learning experience of people through the creation and implementation of activities, technologies and artifacts, where robots play an active role" (Angel-Fernandez & Vincze, 2018).

Robot Kit: A robot kit contains the elements necessary for the complete construction of an operating robot: components needed for building a robot body; sensors (small electronic devices for detecting and measuring things in an environment like light, electricity and temperature); motors to power the robot; gears and other mechanical components; and a small processor. This definition has been developed by Gura (2011) for a brand custom robot kit, but it can be generalized to others.

Stationery Materials: The supporting materials provided to students to design their robots or products during the activities are usually referred to as stationery materials.

CHAPTER 2

LITERATURE REVIEW

This chapter attempts to provide a theoretical background to the research questions set out in the previous section and a review of related studies on these questions in the literature. In detail, the problem-solving perspective of the proposed activities was clarified in the first part of the chapter. The learning environments that permit problem-solving and the use of educational robots were then elaborated with related studies. Additionally, the theoretical framework of the study was established prior to the summary part at the end of the chapter.

2.1 Problem Solving

Duncker's (1945) description among the early ones as "A problem arises when a living creature has a goal but does not know how this goal is to be reached. Whenever one cannot go from the given situation to the desired situation simply by action, then there has to be recourse to thinking (By action we here understand the performance of obvious operations). Such thinking has the task of devising some action which may mediate between the existing and the desired situations" indicates importance cognitive process, thinking, for the problem solvers (p.1). According to this definition, the goal of the problem solver and its distance from the current situation refer not only to operations but also to recourse of thinking. This means in the opposite way; if the problem solver knows operations to reach the desired situation and automatically activates the performance, then the problem does not exist in that situation. When it exists, "the problem-solving can be learned only by solving problems" (Engel, 1998, p.1). In detail, this learning begins by observing and imitating others when they are solving problems, and then by acting in performance because it is a practical skill, like swimming (Polya, 1957).

As the importance and belief that problem-solving skills could be learned began to increase, a number of problem-solving models emerged from studies that explain the process of the problem-solving, such as Polya (1957), Simon and Newell (1971), Bransford and Stein (1993). These models are mostly detailed problem-solving processes in three main steps, including (a) representing problems, (b) searching for solutions, and (c) implementing the solution (Shin, Jonassen, & McGee, 2003). This general problem-solving model fits in with the solution of well-structured problems, in which all the information needed to solve it (goal state, the operations to reach it, etc.) is provided in a problem statement (Goel, 1992; Robertson, 2001). Simon (1973) has preferred to give a list of criteria that a problem statement needs to satisfy in order to be well-structured:

1. Existence of definite criteria for testing solution proposals and a mechanizable process for applying criteria to test the proposals.

2. Presence of at least one problem space containing the initial problem state, goal state, and others needed to solve the problem.

3. All transitions from one to another (as attainable or considerable state changes) can be presented in the problem space.

4. Knowledge of the problem solver about the problem itself can be representative in the problem spaces.

5. If the problem statement directs the problem solver to act in the external world, it means that the definition of the state will change, but the effects of the operations and applications in that state should reflect the complete accuracy of laws of nature that govern that world.

All these features hold one another; the fundamental processes in problem-solving require feasible amounts of computation, and the needed information is effectively available without massive effort.

Although ill-structured problems are thought to be the opposite of well-structured problems with the lack of the features above (Tomiyama, 2006), there is no real boundary between well-structured and ill-structured problems (Simon, 1973). Even between these two problem forms, the problem types have been represented on a continuum by Jonassen (2010) to distinguish needs of learning environments for each problem type. The typology is presented in Figure 2-1.

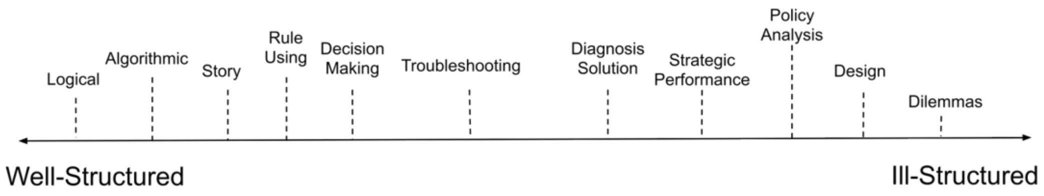

Figure 2-1 Typology of Problems in Structuredness Continuum (modified from Jonassen, 2010).

The need for this typology was expressed by Jonassen (2004) as general problem models tend to act toward all the problems the same, but in fact they were different, and the resolution procedures are not generalizable. For instance, well-structured problems such as logical and algorithmic problems have correct and convergent answers and a predictable and prescribed solution path with a limited number of rules and principles. On the other hand, design and dilemmas of ill-structured problems have vaguely defined or unclear goals and constraints. They have a lot of alternative solutions or no solutions, as in the case of dilemmas. In addition, they are more difficult to solve, and the problem solver can follow multiple pathways in the solution process (Jonassen, 2010).

For learning environments, Sockalingam (2015) classified the structural elements of a problem as (1) content, (2) context, (3) task, and (4) presentation. According to this classification, the content of the problem involves the real focus of the problem, and it reflects the intended learning objectives. The context refers to the background settings of the problem, or a scenario containing the actual problem statement. The expected output of problem resolutions indicates the task element, which determines what learners are required to do. The presentation refers to the form of the problem and specifies the style of learner to deal with the problem. By considering all these elements, the design of a problem in a learning environment involves five steps which are not necessarily linear and can be iterative:

1. Studying learning needs of students
2. Specifying content
3. Selecting context
4. Setting up expectations or tasks
5. Synthesizing the problem

2.2 Problem Solving Learning Environments

The learning settings that encompass problem-solving activities and instructional approaches that use problems for driving and enhancing students' learning refer mostly to problem-based learning (PBL) environments. These settings have evolved into several variations with the degrees of problem structuredness. Among them, the pure PBL model differs from others in that it directs instruction including absolutely no lectures for the sharing of knowledge from instructor to learner with a need to solve authentic and ill-structured problems. Hybrid PBL, on the other hand, provides a limited amount of lectures as supplemental instruction. The dominant instructional method and student learning format in this form are still high levels of self-directed learning, problem-solving initiation, and authentic, ill-structured problem-solving (Hung, 2015).

An architecture consisting of the combination of cases in any problem-solving learning environments, including PBLs, was defined by Jonassen (2010). In one of these cases, the worked examples purposes of enabling the learner to induce and create schemas for ideas. Although these examples are essential for instruction and the most common method for supporting schema construction in problem-solving, they are useful for well-structured problems. In contrast, the case studies should be utilized to support problem schema construction for more complex and less structured problems since the students need to analyze the situation and processes, and evaluate the methods and solution by the guiding problems. When the students examine similar problems (analogies) in the process of problem-solving, they develop a more detailed intellectual understanding of the issues. Another analogy to support problem-solving, prior experience, is directly used by the problem solver without attempting to construct a schema. Searching the nearest case in an organized library of annotated problem cases and re-use refers to the solver's prior experience. If the solving problem itself is dangerous at the moment and experience of it is not available, the simulations should be utilized, and the feedback provided should be enough to confirm or reject the learner’s understandings. Additionally, an alternative perspective required that cognitive flexibility was absolutely necessary for solving more ill-structured problems to construct the problem's personal meaning.

By working with an unknown problem, the students need to get information, look for cues, analyze, and synthesize the available data, develop a hypothesis, and apply strong deductive reasoning to the problem in a PBL (Barrows & Tamblyn, 1980). With problem-based learning, the students' works start with an ill-structured problem that contains a challenge that explicitly links an important issue in the students’ daily lives. This link brings a vital motivational feature as the students engage in the problem-solving (Delisle, 1997). According to Tan (2003), the process of problem-solving in a PBL environment follows (1) meeting the problem, (2) problem analysis and learning issues, (3) discovery and reporting, (4) solution presentation and reflection, and (5) overview, integration, and evaluation steps. Additionally, these steps are expanded for the collaborative ill-structured problem-solving process in a PBL supported with technology (Song, 2005):

1. Review the problem scenario,
2. Defining the problem,
3. Investigating the problem with resources,

4. Proposing group solutions,
5. Presentation of the solution

Significant developments in pedagogical methods have made the learning background accessible, particularly since the emergence of personal computing technology, encouraging the use of problem-based methods that situate the learner in the real-world and among practical challenges (Spector, Lockee, Smaldino, & Herring, 2013). Technology-enhanced learning environments when it covers an attempt to solve a problem and the technology play a role in the solution gives us some idea how computational thinking (CT) is used in any subject area since it involves critical capabilities and patterns to enable the individuals to solve problems more clearly and logically (Beecher, 2017; Krauss & Prottsman, 2016).

2.3 Computational Thinking (CT) as Problem-Solving Process

The use of Computational Thinking (CT) as a term in education traces back to the work of Seymour Papert in 1980 (Angeli et al., 2016). However, its popularity has seen a considerable increase after being defined by Wing in (2006), according to whom, "computational thinking involves solving problems, designing systems, understanding human behaviors, by drawing on the concepts fundamental to computer science" (p.33). In this first definition, the essence of CT is seen as "thinking like a computer scientist when confronted with a problem" (Grover & Pea, 2013). However, new attempts for the definition as "thought processes involved in formulating problems so their solutions can be represented as computational steps" (Aho, 2012, p.832) and as "the conceptual foundation required to solve problems effectively and efficiently (i.e., algorithmically, with or without the assistance of computers) with solutions that are reusable in different contexts" (Shute, Sun, & Asbell-Clarke, 2017, p.1) highlighted it as a fundamental skill for everybody. The common point of these attempts is their focus on the skills, habits, and dispositions of individuals to solve complex problems (Voogt, Fisser, Good, Mishra, & Yadav, 2015). Additionally, Kalelioğlu, Gülbahar and Kukul (2016) proposed a framework for the combination of both scope of CT and the problem-solving process. This framework is given in Table 2.1.

Table 2.1 Computational Thinking as a Problem-Solving Process

Identify the Problem	**Gathering, representing and analyzing data**	**Generate, select and plan solutions**	**Implement solutions**	**Assessing solutions and continue for improvement**
Abstraction Decomposition	Data collection Data analysis Pattern Recognition Conceptualizing Data Representation	Mathematical reasoning Building algorithm and procedures Parallelization	Automation Modeling and simulations	Testing Debugging Generalization

(Kalelioğlu et al., 2016, p.593).

According to Kalelioğlu et al. (2016), the problem-solving process starts with the identification of the problem through abstraction and decomposition. In the next step, several data collection procedures, data analysis, pattern recognition, conceptualism, and data representation should be employed to gather, represent, and analyze the data. In generating, selecting, and planning solutions, mathematical reasoning, building algorithms, and parallelization procedures should be utilized to get more correct solutions. Automation, modeling, and simulation will be in action in the implementation of the solution process. Lastly, to assess the accuracy of solutions, testing and debugging can be taken into consideration. Additionally, the solution should be applied to different types of problems in the final step of the framework. These steps are examined in detail in the following section.

2.3.1 Identify the Problem

Abstraction

According to Wing (2008), abstraction, as the essence of CT, requires the process of "deciding what details we need to highlight and what details we can ignore" when working with real-world problems (p. 3718). Connell, Edwards, Hramiak, Rhoades and Stanley (2015) claim that CT attempts to dispose of the complexity of any situation by hiding details of it in abstraction. Similarly, it is the identification and extraction of relevant data by omitting the irrelevant one(s) to reach the main idea(s) (Bilbao, García, Rebollar, Bravo, & Varela, 2016).

Decomposition

Catlin and Woollard (2014) defined decomposition broadly as taking complex artifacts, systems, and processes to pieces. From a problem-solving perspective, it can be simplified as the ability to break down complex problems into simple, smaller, and easier parts to understand and solve them properly (National Research Council, 2010 as cited in Angeli et al., 2016). These sub-problems can be divided into smaller pieces unless the coherence is lost (Connell et al., 2015). Decomposition enables a better understanding of problems by dividing them into sub-problems.

2.3.2 Gathering, Representing and Analyzing Data

Data collection

Data collection is the way of reaching the information by collecting and recording it (Bilbao et al., 2016). "The process of gathering appropriate information" (CSTA & ISTE, 2011, p.14) is the key preliminary preparation for logically organizing and analyzing data in a problem solving-process.

Data Analysis

CSTA and ISTE (2011) defined this concept as "making sense of data, finding patterns, and drawing conclusions" (p.14). According to Bilbao et al. (2016), previously collected data can be meaningful by finding patterns on it or developing insights.

Pattern Recognition

According to Michaelson (2015), pattern recognition is one of the CT stages, and it means the ability to realize any similarities, differences, or trends. With this ability, individuals look for patterns among problems, which requires taking into account the previous problems to see the similarities or differences between them and the new problem or patterns in the information that need to consider the data structure to find any related organization.

Conceptualizing

Falloon (2015) defines this term as explaining, critically reflecting on data that represents requirements, problems, actions, or the responses of others. The learner can conceptualize the data to self (thinking aloud), with other students (collaboration), or conceptualize with teachers in educational contexts.

Data Representation

Data Representation is "depicting and organizing data in appropriate graphs, charts, words, or images" (CSTA & ISTE, 2011, p.14). This is important for organizing data and to see the whole picture of the data.

2.3.3 Generate, Select and Plan Solutions

Mathematical Reasoning

Mathematical reasoning is applied after discriminating several levels of abstraction in CT (Sengupta, Kinnebrew, Basu, Biswas, & Clark, 2013). Likewise, L'Heureux, Boisvert, Cohen and Sanghera (2012) define logical thinking as the ability to develop and test hypotheses in a problem-based situation. It can be generalized as all the reliable predictions about future steps or behaviors.

Building Algorithm and Procedures

CSTA and ISTE (2011) defined building algorithms and procedures as "series of ordered steps taken to solve a problem or achieve some end" (p.14). This skill encompasses both sequencing and flow of control concepts. Sequencing requires putting the correct sequence of steps in the process of problem-solving. The flow of control is to define a series of these steps in which actions are executed (Angeli et al., 2016). Connell et al. (2015) claim that flowcharts are excellent tools to use the presentation of algorithms. The symbols in any flowchart represent the flow of control and arrows indicate the sequence in the procedure.

Parallelization

Parallelization is introduced as regulation of "resources to simultaneously carry out tasks to reach a common goal" (CSTA & ISTE, 2011, p.15). Dividing data or a task in more than one way to proceed simultaneously is an example process of parallelization in problem-solving approaches (Barr, Stephenson, & Barr, 2011).

2.3.4 Implement Solutions

Automation

CSTA and ISTE (2011) defined automation as utilizing technological devices such as computers to perform repetitive and complex tasks. However, using technological devices is not mandatory for this type of skill. In this opposing view, automation of a process, idea, or algorithm can be considered as the indicator of this skill (Selby & Woollard, 2014). This can be generalized as the automating of solutions (Voskoglou & Buckley, 2012).

Modeling and Simulations

Simulation is the representation of a process or running experiments using models. Using this representation, students can learn if changing something in a process makes the situation better or worse without destroying the real situation (CSTA & ISTE, 2011).

2.3.5 Assessing Solutions and Continue for Improvement

Testing

Testing shows the solutions in action (L'Heureux et al., 2012) that can be considered as the evaluation of the solution.

Debugging

Debugging is the skill of CT, which is described as "determining problems in order to fix rules that are malfunctioning" (Berland & Lee, 2011, p.70). Wing (2006) claims that debugging is the crucial element of both CT and programming. For instance, in the programming process debugging contains three steps. The developer needs to identify a fault location, understand the causes, and modify the codes to fix the program when a software failure occurs (Parnin & Orso, 2011).

Generalization

Generalization is a way of solving new problems quickly by using patterns, similarities, and connections to previous experience on solutions of problems (Csizmadia et al., 2015). It is basically applying the same technique to a similar problem. For instance, an algorithm that served the purpose previously solves a couple of similar problems. Therefore, this general solution should be utilized to solve new problems (Curzon, Dorling, Selby, & Woollard, 2014).

2.4 Educational Robots

Although the goals of education in the past reflected the impact of society on the needed skills such as reading, writing, and arithmetic and the core information for everyone, many educators now agreed on the focus of education on general skills such as problem-solving, collaboration, project management (Chaudhary, Agrawal, Sureka, & Sureka, 2016), creativity, and innovation which will help the learners cope with the rapid technological change to continue to invent and innovate in the future (Eguchi, 2017). With the potential for acclimatization with this necessary change, educational robots gave the learners the opportunity to experience the mechanical, electrical, and computer-based production processes by developing specific areas and skills through the design, creation, assembly, and operation of them (Gorakhnath, 2018). Therefore, "educational robotics is a learning tool that fosters various skills and knowledge essential for every student to take part in creating the future innovations that society needs" (Eguchi, 2017, p.18.).

In fact, the use of robots in education is not a hot topic in the field. The potential of these tools was already recognized by educators a long time ago, but the economic aspect of them prevented the acceleration of their usage in education (Üçgül, 2013). In detail, the introduction of robots in education was rooted in one of them, Turtle, which was launched by Seymour Papert in 1969. The founder of educational robots considered them great potential tools as transitional objects between the students and computers. In the following years, a few educational robotic tools became available and found their ways into learning environments (Catlin, Kandlhofer, & Holmquist, 2018) since they were very expensive, limited, and unsuitable to educational settings (McNerney, 2004). With the decrease in costs, various forms of robots got more affordable for personal usage from the mid-1990s, and they were increasingly accepted as technological tools in learning environments (Keane, Chalmers, Williams, & Boden, 2016) and became a popular learning tool for educational settings (Assaf, 2014). The reason behind the popularity of these tools could also be fundamental in Papert's view of education besides economic reasons. In that view, Papert (1999) explained that education with its two wings resulted from the effects of digital technology on it. In one of these wings, the purpose of learning is to get information from a source such as reading books, listening to a teacher, or visiting a website. In contrast, the learning covers doing, making, and constructing things in the education's constructional wing. The emphasis for those parts should be nearly equal in all educational settings; however, since the absence of suitable technologies, the constructional side of learning stays in the background of the dominant informational side. Therefore, tools like robots enable educators to focus on the contructional side of learning, so they started to become popular in educational settings. Another valuable aspect of their employment in education was expressed by Mubin, Stevens, Shahid, Mahmud and Dong (2013) who used advanced technology on them and produced tangible representation of learning outcomes. This outcome encourages educators in the field to investigate further practical aspects of the utilization of robots in education.

Recently, Cheng, Sun and Chen (2018) conducted a study to investigate robots' essential applications in education. They started this study with a literature review. Then, it was continued with expert views and surveys with instructors to put the robotic applications' requirements in educational settings. Some of the reviewed applications of robots in education showed the fields of language education, social and special education, guided learning, physical, science, and math educations. Additionally, they found that the applications were appropriate for the six age groups of learners, who ranged from preschool to older learners. However, the preschool and primary school levels are found to be the greatest potential groups to implement educational robots in the near future. By referring all these age groups, robots in any educational setting should cover both direct teaching activities and be used for indirect contribution to learning (counseling or classroom management) since they could have the potential to support the learners' formal and informal learning requirements to the researchers.

The experience in the use of robots in both formal (primary and secondary schools) and informal education (after school activities, summer camps) was examined through a systematic review of 16 relevant articles by Kubilinskiene, Zilinskiene, Dagiene and Sinkevicius (2017). The findings of this research indicated that the use of robots in school expands its boundaries increasingly by focusing on a diverse range of fields, from STEM to non-STEM subjects (Social sciences and humanities). The diversity of the robotic tools and the learners' age were considerable in formal and informal education spaces, where the learner can develop a wider range of skills. The most suitable teaching methods in those settings were found to be problem-based, project-based, and competition-based learning theories.

Another review study on robots in education was conducted by investigating several kinds of research in a variety of host countries such as Japan, Korea, Australia, Germany, the USA, and Holland. The cross-country studies indicated the domain and subjects of the learning with the robots. According to the findings of the review, two main categories are technical and non-technical education. In the first field, the primary purpose of the education was to give the students the knowledge of the robots and technology, while the robots were used as intermediate tools to impart some part of the instruction to teach the students non-technical subjects (such as science, mathematics, and geometry). The third one in the literature indicated the use of robots to teach the second language, mostly as a tutor or peer. In all these domains, the robotic applications took place in either intra-curricular or extra-curricular activities. One of the shortcomings in the field of education with robots is that the robotic applications in literature were mostly seen as extra-curricular in informal education (Mubin et al., 2013b).

The aforementioned literature reviews indicated the use of educational robotics in both non-formal and formal educational settings. Since each setting provides specific learning experiences for the learners, the details should be examined separately.

2.4.1 Use of Robots in Extracurricular and Hybrid Applications

The applications unrelated to school curriculum or some hybrid activities that combine out-of-school activities with a part of the curriculum (Benitti & Spolaôr, 2017) refers to the applications in non-formal educational settings in the literature. These non-formal educational settings were mostly found as the afford of afterschool programs such as national or international robotic competitions, summer camps, and workshops for school-age children.

Robotic Competitions

Among the non-formal robotic applications, Robofest (www.robofest.net) is an annual robotics festival with competitions designed to provide a high-quality Science, Technology, Engineering, and Mathematics (STEM) education for K-12 students from different countries. The intended objectives of the festival were announced as (1) to spark young students' interest in science, math, engineering, and technology (2) to promote imaginative, creative, and innovative thinking and ideas (3) to build a globally competitive engineering workforce of the future in reports of the organization, which launched firstly in 1999 (Chung, 2009). The participated students can experience various competition categories that fit multiple interests of learners, learning styles, and methods (PBL: Problem-based Learning, SDL: Self-Directed Learning) during the festival (Chung, 2019). According to the assessment results and surveys conducted in this organization, the Robofest robotic experience promoted better learning about STEM for thousands of students. Notably, the students became more willing to have careers involving STEM fields (Chung, Cartwright, & DeRose, 2017).

Another international competition to encourage students to pursue careers in technological fields was the organization of the First LEGO League (FLL). In this program, the students were given a challenge related to the science field every year, and they work in teams to program a robot to overcome that challenge in a competitive climate with other teams. However, the research findings in the organization indicated that the learning opportunities went beyond just building and programming a robot (Oppliger, 2002). The program also provided the participants "opportunities for learning many 21[st] century skills such as systems thinking, decision making, problem-solving, teamwork, conflict resolution, flexibility, perseverance, and self- management" (Ma & Williams, 2013). Another study's results specifically indicated the importance of problem-solving activities during the eight-week FLL Robotic Challenge in 2004. At the end of this research, the researcher proposed the necessity of teaching technological problem solving into 21st-century elementary school curricula (Varnado, 2005).

Eguchi (2014a) conducted a study about another universal organization, RoboCupJunior World Championship, which was one of the most popular educational robotic competitions, including several countries. This case study investigated the effects of the competition on learning experience, particularly on learning skills, knowledge, and future career choice of only US team members. The study results indicated that RCJ had a positive impact on students' interest in STEM subjects, computational thinking skills, engineering thinking skills, and their future career decisions in favor of STEM fields. In fact, the organization was designed for both elementary and secondary students by offering cooperative and competitive learning environments that introduce a common challenge for three aspects of the program: dance, soccer, and rescue (Lima & Custódio, 2005). These aspects maintained the same goals from one year to next from its' begins in 2000 by providing a scaffolded learning environment with improved competition rules. This was one of the features of the organization that sets it apart from other competitions. The utilized technologies in the recent year of the organization in terms of both low cost in expense and simplicity of usage indicated that they allow participated students to reach more complicated and diversified tasks in their projects by advancing technological awareness and capabilities (Eguchi, 2016).

In addition to these international organizations, national initiatives were also seen as an attempt to introduce the students to advanced technologies. One of those, Teknofest, was started in 2017 as an effort for a technology producing society in

Turkey (Teknofest, 2018 as cited in Ünsal, 2019; Birol & Aydın, 2019). This first program and follow-ups in recent years were supported by several stakeholders from the Ministry of Industry to private foundations and organized as lots of competitions, exhibitions, and workshops. In the section of the organization devoted to the robotics, the teams of the participants (K-12 students) struggled to design and code the best entry in robotic competitions conducted in such themes as line follower, humanoid robots, industrial robot arm, moving robots, design and implementation, egg gathering, and archery categories (Teknofest, 2019). In fact, these categories and the rules of the competition were defined by the Ministry of Education on the basis of the national robot competitions held in previous years. The teams, composed a supervisor and two students, can apply to robotic competitions, which were first held in 2007 and continued as part of Teknofest since 2019. The aforementioned category of the competitions was carried out with pre-determined tasks and special rules. For instance, the teams should complete placing a certain array of objects in a certain order on a platform with a robotic arm working with three axes in total. As this robotic arm category, all of them were evaluated by the referees and coaches during the organization (MEB, n.d.). The reports of the Ministry of Education indicated the goals of such completions in the strategic plan as (MEB, 2016):

- Increasing the quality of vocational and technical education in the country,
- Educating the students at secondary and higher vocational and technical education levels as individuals who use their knowledge and skills, think entrepreneurially, scientifically, and have an awareness of competitiveness,
- Preparing an environment for the students to share their knowledge and experience,
- Raising the awareness about vocational and technical education in the society,
- Promotion and exhibition of studies in the field of industrial automation technologies and robot technologies.

Moreover, the number of participants for the competitions were also given in the reports. According to one of them, a total of 6000 participants participated in the competition in 2019 (MEB, 2020b). According to information on the website, this increased to 8583 with a total of 4063 teams next year. The frequency of the participated teams among the competition categories was quite high for mini-sumo (752) and fast line follower (743) and very low for themed (76) and free project (93) (MEB, 2020a). However, the page and other reports about the organization did not provide extra information about the results of these competitions other than the name of the winning team. Unfortunately, there have been no such academic journals published on the program's educational details yet. Like these competitions, others motivated the researchers to focus on several research topics, and the need for this direction should not be underestimated. However, it can be quite difficult for the students in those learning environments to collaborate and learn from others effectively during the competition itself (Sheh, Eguchi, Komsuoglu, & Jacoff, 2017). Therefore, other research was also conducted on the other non-formal learning environments.

Robotic Camps

Robotic camps were seen as one of the popular application contexts for both extracellular robotic activities and the hybrid activities enriched with school curricula in the literature.

In one of them, a summer camp was introduced to describe a learning environment that consists of lessons, worksheets, and hands-on activities. The camp aimed to examine and observe the problem-solving process of elementary school students in a detailed manner since it is important to develop a curriculum and teaching methodology for such activities. The lessons were composed of direct instruction to design and construct using their components such as motors, sensors, wheels, and connectors. The students also gained knowledge on the programming of robots by using a visual programming environment in these lessons. The worksheets were supportive materials for both assessment of leanings in those lessons and the preparation of the activity problems. In hands-on activities, the students had a chance to practice on the problems which were clearly identified with its' constraints and goals. The study results promisingly indicated that the camp program was effective in imparting the desired skills (such as collaboration, programming, and robotics) and knowledge to students (Chaudhary et al., 2016). Another research on the robotic educational program used in a camp was conducted by Yudin et al. (2017) with secondary school students. The program covered an introduction lecture, an afterschool activity environment, digital fabrication equipment, and a competition with a schedule of two weeks. According to the study results, the competition was successfully completed among the students who mostly have no prior experience in robot building. Even if it was a competitive environment, the students cooperated with others and the educators in their tasks, which require the use of special fabrication machines to build a robot in their project. Additionally, the students' high interests in the program were one of the promising early results of this camp.

In addition to the programs that prioritize the robots, it was seen in the camps where robots were integrated with other fields of education. In one of those, Williams, Ma, Prejean, Ford and Lai (2007) conducted a mixed-methods study that aimed to explore the impact of a summer robotic camp on students' content knowledge of physics and scientific inquiry skills. The camp took two weeks, and the participants studied two and a half hours each day with heterogeneous groups of middle school students. The results indicated that students' content knowledge about physics increased at the end of the camp. However, the project failed to improve their skills in conducting scientific inquiry. In contrast, affordances of the robotic environment in another camp enriched with a pedagogical approach emphasizing open ended and extended inquiry prompted the science literacy-based thinking and science process skills of middle school students when they faced a problem-solving challenge. In fact, the activity in this study required only minimal building for solving a robotic challenge because of the time constraints, which continued approximately 100 hours in a 3 week period. The participants' utilization of thinking skills and science process skills was analyzed both based on observations and empirically in this period of time. The three design aspects of the learning environment of the camp were emphasized by the researchers as (1) the tool-rich nature, (2) the immediate feedback of the system, and (3) open-ended and extended inquiry. According to these aspects, the learning environment in such camps requires tool use from the participants. Sensors on robots, the software program, and measurement are some of these tools utilized in developing solutions to the problems. The immediate feedback refers to two types of feedback in the system. One of them, the software, indicates the programming errors to the user before being uploaded to the robots. In the other one, the learner can see the program's results immediately after the program's upload process for the solution of the problem. In fact, the problem in the camp was enabled by the pedagogical approach with an open-ended and extended inquiry, which allows students to decide how to solve the problem and follow that decision in their solution (F. R. Sullivan, 2008).

Other fields of integration of robotics in education were seen as STEM fields. Four faculty members from Youth Development, Biosystems, Engineering, and Education had collaborated to develop an innovative robotics program for informal learning settings of middle school students. This afterschool program aimed to provide students both hands-on and self-directed learning experiences for personalized comprehension of science, technology, engineering, and math (STEM) concepts using robotics. A quasi-experimental design was selected as a methodology to compare the data of the treatment (robotics) group consisting of 147 students versus the control group (no robotics) involving a total of 141 participants. The study results indicated that the use of such technologies had a positive impact on learning computer programming, mathematics, science, and engineering/robotic (STEM) concepts among youth learners. The motivation and attitudes toward these fields were also affected positively during such implementation in favor of the experimental group (Nugent, Barker, Grandgenett, & Adamchuk, 2009). Besides these positive contributions of the camps in STEM education, Üçgül (2012) conducted a study to examine the robotic camps' design and development issues. Two robotic camps, which were organized for elementary students, were investigated for this reason. According to results that were derived from interviews with students and instructors, observations, field notes, and camp evaluation forms, the ten themes that emerged included learning outcomes, group issues, coaching, challenges, technical issues, competition, career, duration, and evaluation of the camps' components. According to the guideline developed for such camps in this study:

- The content of the instruction should be designed simple to complex in robotic camps.
- The general robotic knowledge should be presented at the beginning of the camp with interesting activities.
- The other STEM concepts should not be given with direct instruction during the camp. Some inquiry methods can be used instead.
- Like real-life problems, some complex problems should be utilized in camps to encourage the students to use their knowledge to solve these problems.
- Since the most effective part of these camps is building a project, all robotic camps should encourage such projects in their instruction.
- Camps should be designed to provide an opportunity for students to bring their acquisition from the school.
- Group size should be arranged to give all members a chance to work at any time of the camp. Three or four members for each group are advised with mixed gender.

Varney, Janoudi, Aslam and Graham (2012) introduced a new program developed from summer camp programs for in-school sessions to foster the interest of students on STEM topics. Since this new program is an alternative to the summer camp programs, the researchers explained the differences between the two programs. The results of this comparison indicated that the in-school program is more flexible than the summer program since the duration allows students to spend more time on individual tasks and topics. The in-school program is more narrowly structured than the summer program, with a focus on gradually building the students' problem-solving skills, teamwork, and mathematical skills. This is possible because of the extended duration of the in-school program, which allows students to spend more time on individual tasks and topics. In the school program, learning is done through lectures. Therefore, the activities in the program take more emphasis on STEM topics. The last difference is about financial and motivational issues. In summer camp, usually, the students interested in robotics and STEM topics enroll in the camp. This camp also requires payment for the enrollment. In contrast, the school program reaches a very diverse profile of students and expects to have a larger impact on students than the summer program.

Workshops / Clubs

The robotic workshops, which were relatively completed in less time than robotic camps, were also in the scope of several pieces of research in the literature. In one of them, Ruiz-del-Solar and Avilés (2004) aimed to share students' and teachers' experiences concerning robotics workshops since 2000 in Chili through surveys. The workshops was organized as extracurricular activities for the school children in K-12 levels and the teachers based on a framework provided by Martin (2001):

- Preparation of students in a workspace dominated by technology,
- Supporting teachers in developing a technologically literate workforce and enabling tools to them to integrate competencies into school activities,
- Developing curriculum modules of robotic education that will reinforce current math, science, and communications standards (as cited in Ruiz-del-Solar & Avilés, 2004).

The researchers asked the degree of satisfaction, level of competence, and students' interest in an engineering career to the participants who have already attended these robotics workshops. The results of three different applications of workshops lasting two-five days indicated that 92% of the participants were satisfied with the workshops, 88% of them finished all the tasks in the workshops, and 86% of the students thought that they would follow an engineering or science career in their future life (Ruiz-del-Solar & Avilés, 2004). Similarly, an enriched after school program with elementary and science curriculum utilized increasingly complex programming tasks. The results of this experimental study revealed that students in the robotics intervention group had a significantly higher academic score on science and technology concepts than the control group (Barker and Ansorge, 2007).

Cavaş et al. (2012) investigated the impact of robotics-based education on students' science process skills, scientific creativity, and perceptions on the robot, human, and society. Students worked collaboratively in after school club groups in which students programmed the robots and conducted inquiry-based activities related to socio-scientific topics. Students' scientific creativity, science process skills, perceptions of both robots and human-society were affected in a positive direction according to the results of the study.

2.4.2 Integration of Robots in Schools

According to Kubilinskiene et al. (2017), the robots were most commonly utilized in non-formal educational settings before, but the tendency of including robots in schools and establishing the links between robotic activities and general curricula is becoming notably important. The teaching practices of these tools may find a wide application in educational contexts. However, more details about them in the school context should be focused on more efficient use in different subjects and applications to a broader range of students' ages. Therefore, the remaining part of the review elaborated on the use of robots in schools.

2.4.2.1 Use of Robots in Curricular Applications

The students' potential improvements from the application of the robots in curricular activities were mostly on problem-solving skills and interpersonal skills such as collaboration, teamwork, and communication skills. The students could also gain experience in scientific processes with the educational usage of the robots. However, the integration of these effective tools into their teaching activities have several potential challenges and obstacles. For instance, inadequate access to support (materials, technical and instructional), time (the lack of preparation time and classroom time), and teachers' lack of readiness (knowledge about robotics and technology skills) are the main obstacles to the usage of these tools in schools. Additionally, some of the teachers perceived robots as an unnecessary topic. They thought that the curriculum outcomes would not be reached by the robots, and the topics that can be covered via robots are very few. These barriers indicated the difficulty of integration of the robots into the learning process, according to the teachers' opinions (Khanlari, 2016).

On the other hand, the students perceived that the robots' features were very similar to human qualities of cognition, affect, and behavior with animistic characteristics (Beran, Ramirez-Serrano, Kuzyk, Fior & Nugent, 2011). They have positive attitudes towards using tangible robots in the learning process. Both boys and girls felt a robot as a friend rather than a teacher in the classroom. Therefore, they were comfortable and happy to interact with a robot in their learning environment (Young, Wang & Jang, 2010). Additionally, students of both genders see the educational robots as a plaything in the learning environment and learning with robots as a source of employment (Liu, 2010). The integration of the educational robotics in the school curriculum may engage all students of both sexes. They can present them career opportunities in the related fields, help them in the meaning of how things work in everyday life, and develop problem-solving skills. The integration of these tools seems to be beneficial for students in many aspects of the learning process. Each aspect of this learning process should be examined and focused on preparing a specific curriculum for the use of educational robots in education (Xenos, Yiannoutsou, Grizioti, Kynigos and Nikitopoulou, 2017).

Robots in Programming Courses

The applications of robotic technology in education are mostly focused on teaching the subjects that are closely related to the field of itself, such as robot programming and robot construction (Mitnik, Nussbaum, & Soto, 2008, Barreto & Benitti, 2012). According to Oddie, Hazlewood, Blakeway and Whitfield (2010), the robots are beneficial for the teaching programming by engaging them in the core task. In that task, they will be encouraged to use tangible parts of the robots. Therefore, these tools offer a real-world environment for learning the abstract nature of programming, such as concepts and vocabulary. As a result, making the programming tangible with robotic activities made the concepts in the course clearer. In detail, when a relatively affordable robotic kit is utilized to teach the fundamental programming skills during a course, overall learning outcomes reached or exceeded the course expectations. Students who learned programming languages via robotic applications will get higher exam scores than others who were taught with the regular curriculum (Hamrick & Hensel, 2013). Additionally, the robots provide a platform for students to improve their weak computer programming knowledge by problem-solving and programming techniques independent of the utilized programming language (Chetty, 2015b).

Park and Lenskiy (2014) developed a platform to improve the educational environment of programming classes. This novel platform enables students to experience several sensors on robots via simulation to reduce the cost of the robotic kits. Additionally, students could access these kits remotely via the network that allows students to program and test their algorithms from home. Therefore, compared to other similar projects, the advantages of this system are seen as low implementation costs and remotely operable features. The results of this study indicated that the majority of students were satisfied with the lab experience, and some others expressed positive feelings about programming with robots (Yousuf, Chaveznava and Hernández, 2006). The implementation also motivated them since the use of robots in the introductory programming course has a positive effect on novice programmers' attitude towards learning (McGill, 2012,) and engages them with authentic, real-world situations in which they can use their programming abilities (Chetty, 2015a). The robotic activities also helped and motivated the students to learn a new programming language. Students had fun with these activities and enjoyed working in mini projects with robots in general for the introduction to a new programming language. The mini-projects in the course improved students' creativity, research, and problem-solving capabilities. However, a few students thought that projects were too simple. Based on technical issues, the robot was reliable in many aspects, but sensors on it failed a few times and needed to be replaced with new ones, according to Huei (2014). Additionally, some technical issues such as connectivity, battery issues, and the workload were seen as frustrating for several students in another programming course. However, this challenging project encouraged students to improve their problem solving and teamwork skills and helped them to develop design skills (Schleter & Biegalski, 2015).

Science Enhanced with Educational Robots

The advancement of robotic technology, as they are capable of investigating and interacting with the real world via components such as sensors and actuators supported with this advance, made them available to new educational fields to aid and foster the relevant topics (Barreto & Benitti, 2012). The nature of science offers students the opportunity to learn with concrete activities through inquiry and hands-on activities. In those activities, the materials would generally lead the students to see science as more interesting and relevant to related subjects (Whittier & Robinson, 2007b). Therefore, the use of educational robots in science education has potential in education, and the interest was the focus of many researchers in the literature. However, some of them selected the science course only, and others added the related fields such as technology, mathematics, art, and engineering in their research.

Whittier and Robinson (2007) designed a course for the unit of evolution in two middle school science classes using educational robotics. The students worked collaboratively to build evolutionary robots (Evobots) and then compare them in terms of different aspects. They wrote reflection papers at the end of the course, which summarize the unit and knowledge of evolution concepts. Nearly all students showed a significantly higher conceptual understanding of the topic of evolution. Three science experiments with educational robots on the subjects of motion, distance, and speed principles were in the scope of another study. A science test, a student's questionnaire, and interviews with teachers were administrated to gather the needed information as a data collection procedure. The study results indicated that the educational robotic kit is an efficient technology to teach these science subjects since it increased the students' academic achievement. Additionally, it is an important technology in primary school environments because it contributed to the development of the students' 21st-century skills (Job & Saeed, 2016).

Koç, Şenol and Büyük (2015) aimed to investigate the effects of instruction supported by robotics on 7th grade students' scientific process skills and motivation towards Science and Technology lesson. The participants of the study were divided into two groups. Whereas the control group stood on the standard curriculum activities about the "Force and Motion" unit in Science and Technology lesson, the experimental group also utilized educational robots for these activities. As a result, the supported laboratory activities are more effective for the development of students' scientific skills and motivation towards the lesson than the traditional activities. These findings are supported by qualitative data that experimental group students expressed that they were very satisfied and fully internalized with the activities supported via robotics.

Additionally, the increase of students' interest and motivation toward both technology and computing and engineering fields was found in several studies. In those, the robots were used in the educational fields of Science, Technology, Engineering, and Mathematics (STEM) fields together (Whitehead, 2010; Üçgül, 2013). Jomento-cruz (2010) examined the effectiveness of a new curriculum enriched with STEM concepts for educational robotic on middle school students' achievement in math and science courses. This experimental study aimed to compare the pre and post-test scores of learning gains within between the group taking additional curriculum to regular science and math courses and the group, which takes only regular science and math. After the ends of ten weeks of instruction, a science post-test that is the same as the pre-test was delivered to both group students. The results of these tests' overall normalized scores indicated that there is not a significant mean difference between the two groups of students' science gain. However, the experimental group's students had significantly higher mean scores in certain GLE (General Learning Expectations such as constructing, using, and interpreting appropriate graphical representations to collect, record, and report data) and scientific inquiry skills.

In a robotic-enhanced learning environment for specific content under the paradigm of STEAM (Science, Technology, Engineering, Art, and Mathematics) education, the students were encouraged to design a fundraising campaign supported by a robotic coin bank that perceives the events around the system, such as coin drops. In this design, the following requirements were put forward:

- With a consistent design of instruction, the students can experience various subjects together.
- Between the expected results of enlarging knowledge, the students can experience affective values such as sharing and caring.
- By the high involvement of students, they can acquire lifelong skills through hands-on activities.

The results of the study describe several procedures for a STEAM lesson. These steps are (1) research, (2) campaign design including image, slogan and interaction design, (3) fundraising campaign, and (4) sharing and reflection (Jin, Chong, & Cho, 2012)

Problem-Solving with Educational Robots

Learning about science and technology and hence becoming scientifically literate does not mean becoming functionally scientific and technologically literate in terms of a component user or practitioner (Hodson, 1992 as cited in Slangen, Van Keulen,

& Gravemeijer, 2011). One of the ideal instructional approaches to become scientifically literate points at problem-solving, since the students who developed problem-solving skills apply correct procedures and scientific decisions appropriately when faced with a challenge (Yuliati, Parno, Hapsari, Nurhidayah, & Halim, 2018). The technology provides the learning environments of problem-solving two important features. The ability of progressive development of problem-solving expertise is one of them. Additionally, the utilized technology personalizes instruction as well as selecting appropriate problems using relevant learning preferences (Spector & Kinshuk, 2011).

Specifically, learning with educational robotics provides the opportunity to practice problem-solving, creativity, and team-work and offers essential skill sets for preparation for the 21st century citizenship (Blancas, Valero, Mura, Vouloutsi, & Verschure, 2020). In order to develop these skills, co-creative problem-solving activities with educational robots seem to be the most appropriate to contribute to the achievement of the learning objectives of K-12 education through a constructivist-constructionist approach. These activities give opportunities to the students to use and develop their own strategies to solve ill-structured problems (Komis et al., 2017). The structure of these activities in which the educational robots are used to solve realistic and authentic problem is given in Figure 2-2.

Komis et al. (2017) discussed a taxonomy in order to differentiate the various problem-solving activities used with educational robots as technology enhancement tools. This taxonomy was constituted on the basis of learners' engagement in the activity process. According to the researchers, the greatest opportunity for development and maintain 21st skills was found in co-creative problem-solving activities. However most instructors have tended to involve students in procedural activities which would not allow them to bring an ill-structured situation into the classroom. On the other hand, co-creative activities make it possible to choose a realistic, ill-structured problem for the real life community. Students work to solve these problems by using both problem-solving and computational thinking skills such as engineering and programming. Developing solutions and new strategies involves construction of a shared vision and planning and coordination within the teams in these activities.

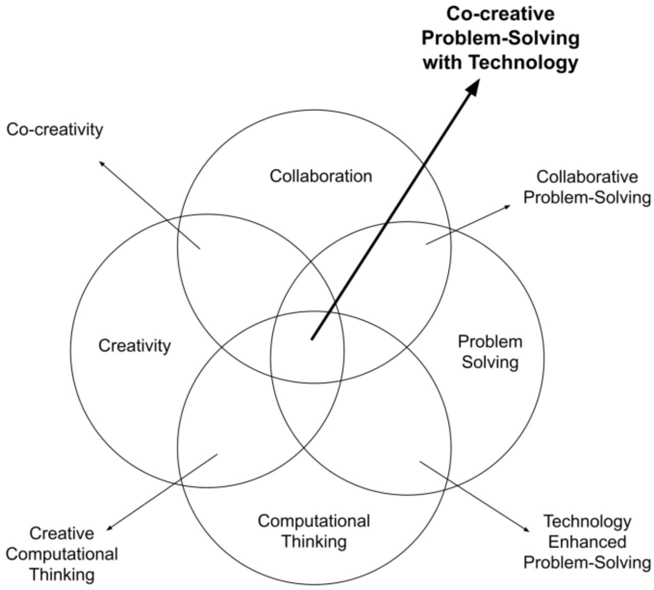

Figure 2-2 Structure of Co-creative Problem-Solving Activities with Educational Robots (modified from Komis et al., (2017))

Another study organized class activities into three phases, including (1) practices (basic closed-ended tasks and exercises), (2) problem-solving (small-scale open-ended tasks in which students can choose the solution method or come with different answers), and (3) projects (open-ended challenges). The research aimed at exploring work patterns, achievements in learning throughout the course, and the impact of the experiences on the motivation of the students. The results indicated that most of the students completed just the basic exercises (first phase), that others did well with the problem-solving tasks (second phase), and that only a few participated in order to carry out a complex project. All students, however, were highly motivated to learn the course subjects. It was obvious that only some students were able to learn a new subject themselves through project work, so that they also had to acquire additional knowledge and skills prior to these problem-solving activities.

A study looked at problem-solving strategies of the students involved in working with robots and their interaction with real-world contexts. The results of the study showed that robotic problem-solving activities helped students to reflect on their choices as problem-solving strategies. The study also revealed that students were able to link their problem-solving strategies to real-world contexts during these activities. While these technological tools were found as highly efficient for resolving real world problems, students' problem-solving strategies must be carefully scaffolded during the process so that they can relate their strategies with robots in authentic situations. Therefore, the design of activities relating students' problem-solving process in the classroom to real-world contexts gains a critical importance in learning environments (Castledine & Chalmers, 2011).

Slangen, Van Keulen and Gravemeijer (2011) studied students aged 10 to 12 participating in problem-solving activities which followed an introduction containing interactive discourses about robotic and practice on programming robots. In the problem-solving task, the students designed, built, and programmed a robot to reach a goal. According to the results, using such technologies helped students develop functional technological literacy by understanding a robot's functions, parts, controls, and operation principles of controls and sense-reason-act loop. They also concluded that learning processes in such an environment should be supported scaffolding by a teacher. This scaffolding should contain asking questions, steering the attention, giving directions, dealing with giving up, giving information if necessary, and helping to solve difficult problems since these interactions helped students to empower their understandings from their experiences. As in another study, flowchart technique can also be used for scaffolding in a constructionist-learning environment in which mixed grades (seven, eight, and nine) students work together in small collaborative groups. According to the study results, students' knowledge and problem-solving skills can be enhanced and supported when the context is constructed with this type of robotic technology, especially scaffolding, which is provided via flowchart techniques. Flowcharting also seems like an effective method for the organization of the ideas by the learners. Groups' efforts to utilize this technique while dealing with a problem indicate a significant increase in critical thinking (Carbonaro, Rex & Chambers, 2004).

In Highfield's (2010) study, a limited scaffolding of the teacher was provided for the extended problem-solving tasks, while more was available for structural and exploratory tasks. The students were required to complete all of these tasks in their weekly activities. The observations indicated that the structured and exploratory tasks together allowed students to develop programming skills. Additionally, the extended one provided them experience to attend to multiple focuses simultaneously. In another study, two different groups of students were assigned to solve a complex robotics-based tasks. The teams utilized two divergent spectrums of task achievability during the problem-solving process, although they used the same problem-solving strategy as trial-and-error. In detail, while one team preferred the use of experience coming from the previous classroom and implementation of procedures that they learned before, the other team tried to construct its own strategy to overcome obstacles faced during the problem-solving process (Blanchard et al., 2010).

2.5 Theoretical Framework

2.5.1 Constructivism and Constructionism

The problem-solving activities in which students face ill-structured challenges with educational robots were strongly linked to two learning theories, specifically constructivism and constructionism, in the current study.

Among them, constructivism might actually date back to Greek time of Heraclitus, but with more focused consideration in learning became available with the work of Piaget (1896-1980) in twentieth century. He described four separate stages of intellectual development of children (sensory-motor, pre-operational, concrete operational and formal operations) and two main process of learning in which individuals dealing with new information with sensory data and use this to build new knowledge and understandings (Pritchard & Woollard, 2010). In addition, radical constructivism creates a new, more tangible connection between knowledge and reality, known as viability. Consequently, an action, operation, conceptual structure or even a theory is considered viable for as long as it is useful to carry out a task or to achieve a goal set for oneself. Thus, it is proper to say, like the pragmatists, that knowledge is a means within the realm of experiences, rather than not claiming that knowledge is able to represent a world outside of us (Glasersfeld, 1998). Therefore, constructivist learning environments assume that knowledge is built individually or socially by learners on the basis of their interpretations of experience. This experience that facilitates the construction of knowledge should be the heart of the instruction to engage the learners in meaning making (Jonassen, 2013).

Papert's constructionism is a theory of learning developed from the Piagetian constructivism. According to Papert (1999), constructionism refers to "learning by making" which is the underlying idea of the theory and it moves the theory beyond the idea of "learning by doing" which is the idea of constructivism. Leaning is the reconstruction of knowledge rather than transmission, and it is more effective when the learner experience is a part of an activity that is the construction of a meaningful artifact (S. Papert, 1987). In 1991, Papert explained the theory with the social perspective of it as:

> *Constructionism—the N word as opposed to the V word—shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe (Papert, 1991, p.1).*

The use of robots in education was rooted in Seymour Papert's constructionism theory. The work of Papert on the programming language, Logo, and programmed robotic, Turtle Geometry, is well-grounded in the literature of robotics and education under the theory of constructionism (Mubin et al., 2013b). Especially, the main characteristic of educational robotics, the artifact that provides the opportunity to the users for both working with and constructing their mental models by programming them with the software, brings them into the constructionist approach (Mikropoulos & Bellou, 2013). According to Alimisis (2013), educational robots are great tools for students to have a constructionist learning experience since they create learning environments in which students have a chance to engage in hands-on explorations to construct knowledge with working on real-world problems.

The instructors can provide a better learning opportunity for students to foster individual learning by robotic problem-solving activities since constructionism emphasizes the use of tools, media, and context to build and share hands on artifacts. The constructionist instructors also design an environment for collaborative learning, where the students encounter a problem to be solved with a meaningful end product with the guidance to reach the goals of the instruction (Rob & Rob, 2018). The settings of such leaning environments can be designed by considering the following frameworks:

2.5.2 Instructional Design for Ill-Structured Problems

Ill-structured problems are solved in an iterative and cyclical process. Therefore, the problem solver needs to proceed differently to solve the problem than the well-structured problem-solving steps. This process is outlined by Jonassen (1997) as:

1. *Articulate Problem Space and Contextual Constraints:* The problem solver decides whether the problem really exists by looking at the problem's nature in this step. Multiple understandings and representations can arise here as one part of the identification of the problem space. The context of the problem is also examined to construct this space. Additionally, the potential causes of the problem, as well as constraints are identified here.

2. *Identify and Clarify Alternative Opinions, Positions, and Perspectives:* The number of problem space will be increased in this step by identifying alternative views or perspectives about the problem. The process will continue with the choice of the most appropriate problem space to solve the problem. Argumentation and judgment should be done among the spaces to find which problem schema is most relevant in this step.

3. *Generate Possible Solutions:* Since the ill-structured problems possess multiple solutions, the problem solver identifies several solution states by analyzing the causes and the constraints of the problem. This refers to a creative process that includes building an own mental model of the problem.

4. *Assess the Viability of Alternative Solutions by Constructing Arguments and Articulating Personal Beliefs:* One of the generated solutions should be preferred against alternative solutions in this step. The development of personal position for the alternative solutions should be set here to support the problem solver decision and justify the chosen solution or reject the remaining solution alternatives.

5. *Monitor the Problem Space and Solution Options:* This step is a metacognitive process where the problem solver reflects on what is known, what is learned before, and the meaning of these. Additionally, the problem solver decides on what others think about the mental model of the problem space, which is highly emergent and dynamic.

6. *Implement and Monitor the Solution:* By the implementation of the solution, the problem solver can consider how persuasive is the performance, which is an acceptable solution, or the solution is satisfactory enough.

7. *Adapt Solution:* The solution is tried out here, and the process would become an iterative process of monitoring, adjusting, and adapting the solution based on the feedback.

2.5.3 Collaborative Problem Solving (CPS)

Nelson (2013) introduced an instructional guideline for problem-based learning environments, which provides valuable collaboration between the problem solvers. This comprehensive guideline addresses the whole collaborative learning process of a problem-solving activity, which begins with the readiness of the group work, and ends with closure to the learning event. This guideline should be implemented when particular conditions, including content, learning environment, and learner characteristics, and the instructor, are appropriate. According to the researcher, the CPS is most appropriate with heuristic tasks, which vary considerably from one situation to another. This makes the guideline an instructional design candidate for an ill-structured problem-solving activity. In activities, ill-structured problem scenarios should be well-conceived for a classroom climate to support small group works and planned carefully to provide enough time for groups to finish their works. Additionally, such environments assign new roles, expectations, and responsibilities to the learners, allowing them to take ownership of their learning. In this self-directed learning, the teacher must be comfortable to less direct the students' control and instruction.

The guideline proposes nine process activities to support a naturally effective problem-solving process. These activities are:

1. Build the readiness to engage in collaborative group work
2. Form the groups and then norm the group work process
3. Engage in the process of preliminary problem definition
4. Define and assign roles for each group members
5. The group engage in iterative collaborative problem-solving process
6. Finalize the solution to the problem
7. Synthesize and reflect on learning process

8. Assess the product and process

9. Provide a closure to the learning event

2.6 Summary

The problem-solving process is a systematic structure, based on the definitions in the literature, where individuals use methods to reach the desired state from a given situation. After the discovery that this process can only be learned by solving problems, the methods used here have become apparent and have been tried in a number of learning environments. The leading learning environments where problem-solving skills can be practiced are problem-based learning environments. This environment starts with giving the student a generally ill-structured problem. Finally, the student, who completes the problem solution using a variety of steps, shares the solution with others. The learning environment can be enriched with specific technologies, so problem-solving can serve as a means of gaining a number of skills involving computational thinking (CT).

When these environments are enhanced by the use of educational robots, we find that both extra-curricular and curricular activities are evident in the literature. The additional result is that the majority of such studies consist of extracurricular or hybrid activities in competitions, camps, workshops, and clubs, and that most of these studies emphasize the need for curricular activities in education. This is the underlying factor of the activities to be generated in the current study primarily for school settings and highly dependent on the curriculum.

In addition, it is seen that robotic activities are integrated into the school environment, mostly with programming courses and science subjects. However, it is noteworthy that there are no guidelines for this integration when the studies are reviewed. Therefore, a study addressing the research question of "How should problem-solving activities for middle school students be designed by using Educational Robotics to solve ill-structured problems in science?" will probably contribute to the literature. Constructivism and constructionism will be the theoretical background for the activities to be developed to find an answer to this research question. In addition, the activity process will be designed through an instructional design model for ill-structured problems introduced by Jonassen (1997) and a guideline for collaborative problem solving (CPS) process by Nelson (2013).

CHAPTER 3

METHODOLOGY

This chapter provides an overview of the methodology used in this study by identifying the purpose and research questions, research design, participants and sampling techniques, data collection tools, data analysis techniques, and issues concerning validity and reliability.

3.1 Purpose and Research Questions

The purpose of the research was to explore the design issues of collaborative problem-solving activities involving ill-structured problems and using educational robots by combining the content of Information Technologies and Software (ITS) and Science Courses for middle school students. In particular, the development of ill-structured problem-solving activities and the problem-solving process of middle school students in these activities were examined in detail. In this regard, the current study aimed to shed light on the effective and efficient use of robotic problem-solving activities in middle schools, to contribute to the related literature, and to provide suggestions on the use of such activities.

In conjunction with the purpose of the study, the main question addressed during the research was: "How should problem-solving activities for the middle school students be designed to solve ill-structured problems in science using Educational Robotics?"

The sub-questions of the research were:

1. What are the enablers and challenges of problem-solving activities designed for middle school students to solve ill-structured problems in science using educational robots?

2. What are the characteristics of problem-solving activities designed for middle school students to solve ill-structured problems in science using educational robots?
3. What are the guidelines for problem-solving activities designed for middle school students to solve ill-structured problems in science using educational robots?

3.2 Research Design

A formative research design was employed to investigate the research questions of the current study. As these questions required a detailed investigation of problem-solving process of activities, this makes it a candidate for a qualitative research approach. According to Merriam (2009), qualitative research primarily purposes to " achieve an understanding of how people make sense out of their lives, delineate the process of meaning-making, and describe how people interpret what they experience" (p.14). Qualitative research strategies therefore give meaning to life-forming events (Berg & Lune, 2014).

According to Van Maanen (1979), qualitative research is an "umbrella term" covering techniques for interpreting certain natural phenomena in order to make them more meaningful to others in their natural context (p.520). Within this broad approach, Creswell (2007) identifies several methods, each of which has different focuses, resulting in a diversification of research questions, sample selection procedures, data collection and analysis techniques, and ways to write them up. Among these methods, formative research methodology has been chosen for this study. According to Reigeluth and Frick (1999), formative research seeks to find improvements in the instructional design theory to make it better for education. The fundamental logic of formative research is to find the weaknesses of the applied design theory in order to see the reflections of the faults and then try to overcome these faults with improvements to reach the intended theory (Reigeluth, 1989 as cited in Reigeluth & Frick, 1999).

Formative research, according to Reigeluth and Frick (1999), traces the case study approach defined by Yin (1984) as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2008, p.18) and the researcher hopes to gain an in-depth understanding of this phenomena (Hancock & Algozzinehey, 2006). The phenomena can be classified into two types on the basis of whether or not the investigation is being manipulated in formative research designs. These classes are referred to designed cases and naturalistic cases, respectively. In designed cases, the researcher instantiates the theory before the formative evaluation of the design. On the other hand, in naturalistic cases the researcher finds an instance that is not designed specifically with the theory itself but has the same objectives and context as the theory itself. In addition, observation may be carried out during or after practical application of this theory for naturalistic cases. As a result, there are three types of formative research designs (Reigeluth & Frick, 1999):

a) Designed cases: The theory is deliberately instantiated for research usually by the researcher.

b) In vivo naturalistic cases: The formative evaluation is performed during the application of an instance that is not specifically designed in accordance with the theory.

c) Post facto naturalistic cases: The formative evaluation is done after the application of an instance that is not specifically designed in accordance with the theory.

All these types of formative designs can be carried out to upgrade an existing theory or develop a new one (Reigeluth & Frick, 1999). Therefore, it can be said that the purpose of the research is also significant for formative research design studies.

According to Reigeluth and Frick (1999), the main concern of theory (or a guideline, or model, etc.) building studies is preferability, which means that some methods are more appropriate for achieving the desired outcome than others. The degree of suitability is determined by three dimensions of the values for a theory. These dimensions are:

Effectiveness: Effectiveness is the extent or degree to which the implementation of the theory (or guideline or method) has achieved the objective in a given situation. This can generally be measured as a numarical scalle or observed by the consistency of repeated trials.

Efficiancy: Efficiency is about the question of whether the resources (time, money, effort, energy) are used in the most appropriate way to meet the need of the instruction. A balance for the effectiveness and the cost of the design must be properly set in order to get the required efficiency in the best way.

Appeal: This is a question of how pleasant the resulting designs are for all people involved in the desing. For instructional designs, these people are undoubtedly teachers, students, support people, administrators and parents.

All three of these dimensions should be reflected in the research design for design knowledge generation (Reigeluth & Frick, 1999). The current study was therefore intentionally aimed at developing effective, efficient and attractive collaborative problem-solving activities with educational robots for middle school students. The guideline generated at the end of the research is expected to be an attempt to generate knowledge for the instructional theory developed for such activities in the future.

3.3 Participants of the Study

Participants for Preparation of Activities

The activities were designed and developed on the basis of a literature review concerning the framework of the study and the opinion of experts or practitioners in the field of education. They therefore participated in the study in the preparation phase of the activities prior to the implementation process. Demographics and the phases in which they participated in the preparation of the activities were presented in Table 3.1.

Table 3.1 Participants of the Preparation Process of the Activities

Participants	Gender	Age	Professional Experience	Field	Phase
E1	Male	30	7	IT	ACS
E2	Male	35	11	Science Education	ACS
E3	Female	29	8	Technology and Design	ACS
E4	Male	30	6	Science Education	Suggestions
E5	Female	29	6	Science Education	Suggestions
E6	Female	28	4	Science Education	Suggestions
E7	Female	34	9	Science Education	Suggestions
E8	Male	33	8	IT	Scenario Development
E9	Male	31	8	IT	Scenario Development
E10	Male	35	11	Science Education	Scenario Development
E11	Female	29	7	Science Education	Scenario Development
E12	Female	33	12	Science Education	Scenario Evaluation
E13	Male	35	6	IT	Scenario Evaluation
E14	Male	36	10	Science Education	Scenario Evaluation
E15	Male	32	8	IT	Scenario Evaluation
E16	Male	35	6	Turkish Teaching	Scenario Check
E17	Male	26	4	Turkish Philology	Scenario Check

Analyis of Current Status (ACS) was a decision-making anaysis for the design and development of the activities at the beginning of the study. This analysis was carried out at a focus group meeting with three practitioners in the first cycle of the implementation school. Table 3.1 provides the demographic information of the volunteers involved in this meeting. According to these data, two participants in the meeting were male. One of them (30 years old) had spent seven years in the field of

IT and the other one (35 years old) in science educaton for 11 years. The last participant was 29 years of age. She was one of the school administrators and had eight years of professional experience in the field of technology and design.

With the information obtained from the analysis of the current status in the implementation school, separate interviews were held with four science teachers who had previously experienced robot kits to be used in the study. The aim of these interviews was to gather their suggestions for activities on the basis of these participants' experiences. Three of the teachers who volunteered to take part in these interviews were female. The eldest of these female science teachers was 34 years old and had been teaching science at the school for nine years. The youngest of them was a 28-year-old teacher with four years of teaching experience. The other female teacher was a 29-year-old teacher who had worked in the field of science education for six years. Besides them, the only male teacher who could be interviewed here was a 30-year-old participant with six years of experience in the same field.

Since the activities were based on ill-structured problems, the development of these problems was very important during the preparation of the activities. The problems had to be created in line with the subjects of Science and ITS Courses. For this reason, a focus group meeting was held with teachers and experts (one from IT, two from science and the researcher himself) to create ill-structured problem scenarios. According to the demographic information collected from the participants, one of the teachers was male, 35 years old, and had 11 years of professional experience in the field of science education. In addition, a science field expert who was female and 29 years old participated in the meeting. She had seven years of professional experience in the field. The rest of the participants were male. One of them was 31 years old and had worked as an IT teacher for eight years. The final participant in this focus group meeting was the researcher himself, who had worked for eight years as a research assistant in the field of IT when the meeting was conducted.

The developed activity scenarios were evaluated by four experts separately. The main purpose of this evaluation was both to reduce the large number of activities (seven in all) to a viable level and to determine the order of the activities during the implementation process. The evaluation was carried out by participants with an instrument called an Activity Scenario Evaluation Form, which contains items on the general characteristics and the structured level of the problem scenarios. According to the demographic information provided in Table 3.1, one of the participants of this evaluation was female, 33 years old, and the most experienced participant of the group with twelve years in the field of science education. The second most experienced participant was in the same field, and he was 36 years old, with ten years of experience in science education. The remaining participants were both males, 35 and 32 years of age, with six years and ten years of experience in the field of IT.

The ill-structured problem scenarios selected and listed, depending on the opinions of the experts, were finally reviewed by two linguists. One of them was a 35-year-old Turkish Language Teacher with 6 years of experience. The other expert was a 26-year-old male with four years of experience in Turkish philology.

Participants of Cycle-1

In the current study, the implementation process of the prepared activities was carried out over two different cycles. One of the participants in these cycles was the same. In detail, a 30-years-old male teacher participated in the implementation process of the activities. He had been teaching the content of the ITS Course to the students for seven years. In addition, he had taught robotic programming in these courses for three years at the beginning of the implementation process. During the first cycle, he was working in a public middle school as an ITS course teacher and as the Information Technology Counselor at the same school.

In addition to the ITS teacher, a total of 24 students participated in this cycle of the study. In detail, the activities were carried out with the 5th grade students studying at a public middle school during this cycle. Although the classroom had a heterogeneous gender structure, it was unfortunately not sufficiently heterogeneous in terms of students' success level due to the policy followed for establishing the classes during student admission. Under this policy, the students were assigned to classes at the beginning of the year on the basis of their primary school academic achievement scores. One of these classes was selected for the implementation of the activities. Participating students in this classroom, with their demographic information, academic performance in the previous semester and attendance status for the activities, were presented in Table 3.2.

Table 3.2 Demographic, Academic Performance, and Attendance Status of Participating Students in Cycle-1

		Academic Performance			
Participants	**Gender**	**ITS**	**Science**	**GPA**	**Attended Activities**
S1	Male	88	82	86.02	A1, A2
S2	Male	90	93	86.01	A1, A2, A3, A4
S3	Male	90	81.33	78.67	A1, A4
S4	Male	75	86	82.22	A1, A2, A3, A4
S5	Male	75	77.16	80.13	A1, A2, A3, A4
S6	Male	80	74.83	76.47	A1, A2, A3, A4
S7	Female	92.50	75	86.56	A1, A2, A3
S8	Male	90	85.66	88.03	A1
S9	Female	88	81.09	86	A1, A2
S10	Male	95	76.50	84.10	A1, A2
S11	Female	77.50	76.83	89.46	A1, A2, A3, A4
S12	Female	92.50	87.66	92.32	A1, A2, A3, A4
S13	Female	92.50	85.50	91.55	A1, A2, A4
S14	Female	88	81.05	86.01	A1, A2, A4
S15	Female	95	88.33	94.97	A1, A2, A3
S16	Female	90	70	85.66	A1, A2, A3, A4
S17	Female	100	78.33	91.31	A1, A2, A3
S18	Female	100	78.66	89.09	A1
S19	Female	92.50	76.66	88.47	A1, A2, A3
S20	Female	100	90.50	94.40	A2, A3, A4
S21	Female	88	81.06	86.03	A2, A3, A4
S22	Female	90	89.16	87.91	A2, A3, A4
S23	Female	90	78.33	87.09	A2, A3
S24	Female	85	81.33	83.88	A2, A3

According to data given in Table 3.2, eight of 24 students who participated in the first cycle were male and the other 18 were female. Examining the academic performance of the students in the previous semester, it was seen that the students with the lowest academic achievement in the ITS Course were two male students, S4 and S5, with a score of 75 out of 100. On the other hand, the highest score (92.50) in the same course belonged to four female students (S7, S12, S13, and S19). When the grades in the Science Course of the previous semester were examined, it was shown that the lowest grade (S16 with a score of 70) and the highest grade (S20 with a score of 90.50) belonged to two female students. When looking at the student report grade, in which the average of all courses was taken, it was found that S6, a male student, had the lowest academic performance in the previous semester. On the contrary, the student with the highest average score was a female student in this semester (S15 with score of 94.97). As can be seen from these grades, the grade point averages and individual course grades of the students in the class are 70 and above. This might be an indicator that the first cycle of implementation was conducted with a group of students who were not heterogeneous in terms of the success level which was expressed by the teacher and administration prior to study.

The data in Table 3.2 also shows the status of students attending each activity. Accordingly, the number of students participating in all activities was only seven at the time of implementation. Nine of the other students participated fully in three of the activities. It was seen that six students were only able to participate in half of the four activities. In addition, there were two students who were only able to participate in one of the activities of this cycle. When we look at the status of participation on the basis of activity, the highest number of participants in this cycle was in the second activity with 21 students. Close to this, the first activity was held with a total of 19 students in the first week. In the third activity, the number decreased slightly and the activity was completed with 16 students. The last activity took place with the participation of only 13 students. The lack of participation in some activities can be explained by the fact that the schedule of activities in the school environment coincided with the end of the year. According to the information obtained from the teacher and the administration, there was a significant decrease in student attendance at this school especially in the last month when the exams were over. In addition, the activities took place in this school during the month of Ramadan. It was learned from the same sources that some students' willingness to go to school decreased this month because they were fasting and preferred to stay at home during the school hours.

Participants of Cycle-2

In fact, the second cycle of implementation was initially planned to take place in the same school with a different class. However, the IT teacher who took part in the first cycle was appointed to another school in the same city following the completion of this cycle. It was therefore decided that the second cycle would take place in this new school. The new school was a vocational secondary school where a number of common courses (such as Science, ITS, and Math) were held in the previous school curriculum. In addition to these common courses, the students also had a number of vocational courses, such as Basic Religious Knowledge, Arabic, Koran, and Life of the Prophet. In addition, classes have been formed by separating students according to their gender in the school. As a result, the second cycle of implementation was followed by the selection of classes from both boys and girls in this school. Furthermore, the grade level of the students was also different from that of the first school in this cycle, since 6^{th} graders were chosen here in order not to wait for a term to cover subjects in both the Science and ITS Courses in the 5^{th} grade. These participating students were presented with academic performance in previous year and attendance status in activities in tables below based on the classes (Table 3.3 for girls, and Table 3.4 for boys).

According to data presented in Table 3.3, one of the classrooms chosen for the second cycle of implementation consisted of a total of 21 female students. When examining this group's academic performance in the previous year, the student with the lowest level of academic achievement in the ITS course was found to be S16 with a score of 60.75 out of 100. In contrast, the highest grade student in this course was S12 with a score of 95.75. While the lowest grade in the previous year's Science Course was 55 (S2), it was seen that the highest grade in this course was S12 with a score of 87.60.

Table 3.3 Academic Performance and Attendance Status of Participating Female Students (6/A Class) in Cycle-2

Participants	Academic Performance			GPA	Attended Activities
	ITS	Science	Turkish		
S1	94.75	77.20	90	90.18	A1, A2, A3, A4
S2	70.50	55	67.6	73.21	A1, A2, A3, A4
S3	94	93	100	96.36	A1, A2, A3, A4
S4	82.75	61.77	76.44	79,90	A1, A2, A3, A4
S5	95	90	95.6	96,50	A1, A2, A3, A4
S6	89	78.08	84.02	83.33	A1, A2, A3, A4
S7	81.75	59.60	82.7	84.04	A1, A2, A3
S8	70.75	60.80	79.5	83.80	A1, A2, A3, A4
S9	82	78	93.6	94.35	A1, A2, A3, A4
S10	94.75	69.50	92.3	93.80	A1, A2, A3, A4
S11	77.75	55.30	75.1	80.29	A1, A2, A3, A4
S12	95.75	87.60	97	95.90	A1, A2, A3, A4
S13	81.50	75.20	91.3	86.18	A1, A2, A3, A4
S14	89	79.01	84.08	83.95	A1, A2, A3, A4
S15	94.25	75.70	98.3	92.80	A1, A2, A3, A4
S16	60.75	44.30	57	69.09	A1, A2, A3, A4
S17	65.25	58.60	52.1	73.80	A1, A2, A3, A4
S18	81.50	75.30	90.1	92.09	A1, A2, A3, A4
S19	80.50	73.30	85.6	84.20	A1, A2, A3, A4
S20	90.75	78.8	94.6	92.70	A1, A2, A3, A4
S21	85	55.10	80	75,46	A1, A2, A3

In addition to these two courses, the previous year's Turkish Course grades were also used to form the groups in the second cycle. The underlying reason for choosing this additional course for the creation of the group was that the students in the first cycle had defined the tasks in their group works on the basis of division of labor. One of those tasks was to fill the activity sheet in the groups. When this case was shared with one expert, he/she suggested adding this course grades which might give students background information on writing and reading comprehension skills into the group forming process. Accordingly, the Turkish Course grades of the students were taken into account at the beginning of this cycle. The data in Table 3.3 indicated that the lowest grade belonged to S16 with a score of 57, while the highest grade was 98.30 (S15) for the Turkish Course in female class. Additionally, it was observed that the lowest average grade was 69.09 (S16), while the highest grade average was 96.36 (S3) in this class when the grade point averages of the students were examined in the previous year.

The participation of students in the activities was also shown in Table 3.3. According to this data, the participation rate of female group students in the activities was quite high. It was found that only two students (S7 and S21) did not take part in the last activity. The remaining students participated in all activities throughout the implementation process.

Similar data were provided for the male student class in Table 3.4. The activities in this group continued with a total of 30 students, but there was an exchange of students with other classes during the implementation process. According to this change, five students (S8, S17, S22, S23, and S28) moved to another class after participating in the first activity in this class, and they therefore left the study. Five new students (S4, S12, S16, S27, and S31) who came from other classes on the other side were included in the study starting from the second activity. As these two groups of students were presented below, a total of 35 students with academic performance in the previous year and attendance status in the activities were also shown in Table 3.4.

According to data concerning the academic performance of the male student class in the previous year, the lowest grade for the ITS Course was a score of 59.50 out of 100 and this score belonged to two students as S25 and S31. Among these students, S31 was one of the students who took part in the study after the exchange of students in other classes. In contrast, S21 had the highest score (92.50) for the same course in the previous year, according to data in Table 3.4. When examining the academic performance of this group in the Science Course, the student with the lowest level of academic achievement in science was identified as S9 with a score of 40.33. On the other hand, the highest score 91.88 belonged to S35 in the previous year's Science Course.

Table 3.4 Academic Performance and Attendance Status of Participating Male Students (6/D Class) in Cycle-2

Participants	ITS	Academic Performance Science	Turkish	GPA	Attended Activities
S1	70	43.30	43	63.84	A1, A2, A3, A4
S2	82	55	72	75.13	A1, A2, A3, A4
S3	83	58	70.40	75.75	A1, A2, A3, A4
S4**	75.25	48.33	58.66	64.14	A2, A3, A4
S5	85	81.50	87	87.79	A1, A2, A3
S6	84	57.50	73.80	74.15	A1, A2, A3, A4
S7	80.75	55	70.40	75.13	A1, A2, A3, A4
S8*	81	56.40	72	76.79	A1
S9	60.75	40.33	57	60.59	A1, A2, A3, A4
S10	90.75	77.20	84.70	90.60	A1, A2, A3, A4
S11	96	75.30	91	88.89	A1, A2, A3, A4
S12**	71.50	46.66	50.66	60.72	A2, A3
S13	81	64.80	55.80	66.65	A1, A2, A3, A4
S14	72.75	63.50	61.80	68.36	A1, A2, A3, A4
S15	77.50	52.22	56.33	62.79	A1, A2, A3, A4
S16**	80.75	65.30	73.80	83.89	A2, A3, A4
S17*	74.25	50.11	50.55	62.97	A1
S18	80.50	61.50	74	81.30	A1, A2, A3, A4
S19	73.50	73.30	87	88.60	A1, A2, A3, A4
S20	86	74.30	76.20	82.29	A1, A2, A3, A4
S21	92.50	76.55	62.50	79.60	A1, A2, A3, A4
S22*	74.25	48.50	75.60	76.79	A1
S23*	85.50	66.30	89.50	88.49	A1
S24	74.50	47	70.60	77.18	A1, A2, A3, A4
S25	59.50	52.30	55.60	68.57	A1, A2, A4
S26	90.25	50.20	80.60	77.06	A1, A2, A3, A4
S27**	81	56.40	51.60	70.27	A2, A3, A4
S28*	70.75	51.10	70	71.14	A1
S29	75	45.70	49.70	67.49	A1, A2, A3, A4
S30	88	65.80	85.30	86.07	A1, A2, A3, A4
S31**	59.50	46.66	45.83	58.50	A2, A3, A4
S32	90.50	69.10	75.60	87.21	A1, A2, A3, A4
S33	80	57.50	70.60	74.15	A1, A2
S34	82	68	70.40	85.42	A1, A2, A3
S35	85	91.88	81.88	86.15	A1, A2, A3, A4

* Student left the implementation, ** Participating student later

Although the lowest grade in the previous year's Turkish Course was 43 (S1), it was seen that the highest grade in this course belonged to S11 with a score of 91. In addition, it was found that the lowest grade average (58.50) belonged to S31, who participated in the study after the student exchange process, while the highest GPA score was 90.60 (S10) in the male class when the grade point averages of the students were examined in the previous year.

The data provided in Table 3.4 also indicate the status of male students attending each activity during the implementation process. As a result, 21 students in the group participated in all four problem-solving activities. Seven of the other students participated in three of these activities and two students participated in only two of the activities during the implementation process. In addition, there were five students who were only able to participate in one of the activities (Activity-1) of this cycle. All these students could not continue their activities because of the compulsory exchange of students in the school. The status of student participation on the basis of each activity was also identified with the help of data presented in Table 3.4. According to these data, a total of 30 male students participated in the first two activities at the beginning of this cycle. The third activity was carried out with a total of 28 students and the number slightly decreased for the last activity with the participation of 26 students.

Participant Selection

In the current study, a sample selection methodology based on nonprobability sampling has been employed in a broad sense. Participants are selected intentionally in this type of selection because they are “available, convenient and represent some characteristics the investigator seeks to study”. It is used when the main purpose of the research is not “generalizing findings to a population but only describing a small group of participants in a study” (Creswell, 2012, p.142). Key selection elements should be defined by the researcher in the research, according to Merriam (2009).

A purposeful sampling method was employed for the selection of the participants in the current study. However the selection criteria have changed depending on the phases of the study. For example, the participants in the focus group of analysis of the current status were determined by considering both the implementation school and the fields of the participants. This analysis was therefore carried out with participants from the fields (IT and science education) related to the activities and a participant from the administration. Similarly, while designing the activities, suggestions were taken from four science teachers who had used robots before. Afterwards a focus group meeting was set up to prepare event scenarios. The participants in this group were practitioners, an expert in science, and the researcher himself in fields related to the activities. Experts from the same fields were selected in the scenario evaluation group and two linguists were chosen to review the activities prior to the implementation process.

During the implementation process, the criteria for selecting the participants were twofold, one relating to the students and the other to the instructor. As the activities involved ill-structured problems, students had to have prior knowledge of subjects related to activities involving first-term subjects of the 5^{th} grade middle school curriculum. For this reason, students in the second term of the 5^{th} grade in the first cycle and 6^{th} grade in the second cycle were included in the current study. In addition, an experienced teacher on programming and robotics was selected on the basis of the second criterion. As a result, the teacher who had taken an in-service robot program and had a certificate on the competence to teach this subject was chosen as a participant in the current study. He had also been teaching the subject of robotics to the middle school students for three years.

Since it was planned to observe all participants before and during the activities and all their documents were analyzed, no sampling method for the selection of these participants was specified here. However, after each activity, a method of purposeful sampling was used to select student groups to be interviewed at the focus group meetings. The criteria for this selection were the variations of the groups. Students from different groups interviewed in previous activities were selected to have access to different student experiences after each activity throughout the implementation process.

3.4 Data Collection Instruments and Process

The primary data collection methods were interviews with participants, documentation, and researcher observation in the current study. All these methods and data sources were summarized in Table 3.5.

Table 3.5 Summary of Data Sources and Instruments for Current Study

Method	Data Collection Instrument	Data Sources	Description
Interviews	Focus Group Interview Protocol for Analysis of Current Status	Teachers and administrator at implementation school	At the beginning of the study, a focus group meeting was held at the implementation school to learn about the current state.
	Semi-structured Interview Protocol with Teachers	Science teachers	Suggestions from the science teachers who used robots in the past were received with interviews to design and develop activities.
	Focus Group Interview Protocol with Students	Students in both cycles	Interviews were held with students who worked in groups during the activities to obtain opinions on the experience of each activity.
	Semi-Structured Interview Protocol with Teacher	IT teacher	Interviews were held with the teacher to obtain opinions on the implementation of each activity.
Documents	Ill-structured Problem Scenario Development Form	Teachers, expert and researcher	The proposals for ill-structured problem scenarios were drawn up in a focus group meeting with teachers, an expert and the researcher.
	Problem Scenario Evaluation Form	Experts	In order to select and sort out the prepared activities during the implementation process, the ill-structured scenarios were distributed to the experts and their opinions were collected with the help of a form.
	Science Achievement Test	Students in both cycles	The test was adapted by researcher to determine the

Table 3.5 (cont'd)

			achievement of students in related science subjects.
	Unplugged Algorithm Quiz	Students in both cycles	A quiz was prepared and used to determine the academic achievement of the subject of algorithm in ITS course.
	Activity Sheet	Student groups in both cycles	Activity sheets used by student groups during the activities were used as supporting data sources to explain the process.
	Reflective Diaries and Drawings	Students in second cycle	In order to examine the activity process more closely, the students were asked to draw on the activity time and to write a reflection on their experience in the second cycle.
Observation	Structured Observation Form for Activities	Student groups in both cycles	It was planned to take notes during the activities and an observation form was prepared for this purpose.
	Unstructured Observation Before Activities	Student groups in both cycles	The student groups targeted in both cycles were observed by the researcher in the learning environments before the activities.

3.4.1 Interviews

Focus Group Interview Protocol for Analysis of Current Status (ACS)

Semi-structured interviews with participants, guided by the research questions of the study, were one of the main data sources for the current study. The data collection process began with one of the data collection techniques, a semi-structured focus group interview for analysis of current status at the beginning of the research. The interview protocol with four main questions and thirteen sub-questions were prepared prior to the examination. These questions were specifically addressing the strength, weaknesses, opportunities and threats for the implementation of the activities. For the creditability of these questions, an expert from the field of IT reviewed the protocol and a number of changes on it were made on the basis of suggestions. Questions were also piloted with a teacher to ensure the clarity of the language of the questions. The used interview schedule followed during the data collection process is provided in Appendix A. For the examination, a semi-structured interview was conducted during a focus group meeting with three participants who were teachers from different fields (IT, Science, Technology and Design). One of these teachers was also working at the administration department in the implementation school. The duration of this meeting of the focus group lasted almost 55 minutes.

Semi-structured Interview Protocol with Teachers

A further interview was conducted with four volunteer participants in the preparation part of the activities. Semi-structured interview protocols were prepared to reveal the suggestions of science teachers on proposed activities regarding their past experience. The prepared protocol was reviewed by an expert and piloted with a research assistant in the field to establish the credibility of the instrumentation. The schedule with a total of twelve questions and their probing questions was ready before the interviews. One of these questions, with seven probing questions, addressed the experience of participants in their courses. An additional five questions were about the general issues on proposed activities and these questions were related to the suggestions of the participants on the activities. With the remaining questions, the participants were asked to express their opinions on the issues identified as potential barriers to the implementation of the activities in the analysis of the current status. This interview protocol is provided in Appendix B. For the purpose of applying this examination according to this protocol, three science teachers were interviewed online for approximately 30 minutes each. One teacher preferred to answer questions in writing. Therefore the data from this participant was received via e-mail.

Focus Group Interview Protocol with Students

Following each activity during the implementation process, focus group interviews were conducted with students who worked collaboratively in groups. A semi-structured interview protocol was prepared to provide students with an insight into the activities to address research issues at these meetings. The questions were mainly prepared on the basis of a literature review of the study framework and methodology. More specifically, the interviews began with the opening question: “How would you describe this activity to a friend who could not attend it?”. Three additional questions addressed the problem solving process in the activities with several probing questions. Two more questions asked what makes things easier and more difficult during the activity process. Moreover, students’ opinions about this process were probed with two questions addressing both positive and negative aspects of it. Finally, the potential contributions of the activity and where and how the students could use these contributions were investigated with two questions and several probing questions during the focus group meetings.

The interview protocol was prepared before the implementation process, following two expert reviews and a linguistic check. Additionally, it was piloted with a student of the target age group for clarity of voice. The required modifications have been made to it. The last version of this interview schedule is given in Appendix C. A total of seven focus group meetings with 18 students in the first cycle and 14 other meetings with 44 students in the second cycle were conducted during the study. The duration of these focus group interviews was approximately 15 minutes for each group.

Semi-Structured Interview Protocol with Teacher

After each activity, an interview protocol was also used for interviews with the teacher. This protocol consisted of three main parts, which included questions about the nature of the activities, facilitating and complicating elements of the activity process, and the contribution of the activities. In detail, the interview protocol began with an opening question asking the overall assessment of the activity. The following three questions investigated the teaching process of the activities. Nine additional questions focused on the problem-solving process of students in the first part of the protocol. There were six questions in the next part about the details of the activity process. These questions sought to determine the positive and negative aspects of the activities and the demands for change. Finally, the contribution of the activities was investigated by two main issues in the protocol, as illustrated in Appendix D. In order to construct this interview protocol, as in the case of student interviews, the literature on framework and the methodology of the study were taken into consideration. However, since some of these questions were about the general form of the activities, there were two forms in this protocol. Accordingly, after the first and last activity, a long version of the protocol was used and a short version of it was used for the remaining activities during the implementation process. These two versions of the interview schedule were reviewed by two field experts and they were piloted with a field teacher before the implementation for the creditworthiness of the instrument. During the implementation process, these interviews with the teacher took about 45 minutes for the short form (during the second and third activities) and 1.5 hours for the long version prepared for the first and last activities.

3.4.2 Documents

Ill-structured Problem Scenario Development Form

After receiving suggestions from the practitioners for the proposed activities, a focus group meeting was conducted with field experts and teachers on the preparation of ill-structured problem scenarios. This focus group meeting included the researcher himself, two teachers from the field of IT and science, and an expert from science as participants. During the meeting, participants discussed the issue of the problem scenario, the scenario presentation method, the name of the activity, the objectives of the activity, the related subjects in both Science and ITS Courses, and the equipment needed to solve the problem. The data was recorded via voice recorder and also entered in a form designed by the researcher for this meeting (Appendix E). This form included the filling of parts for the topics mentioned above (problem scenario, scenario presentation method, activity name, objectives, related subjects, and equipment). The meeting lasted approximately 50 minutes and the views of the participants were recorded in the form during this period.

Problem Scenario Evaluation Form

In order to prepare the activities, activity problem scenarios were presented to the field experts. Four experts assessed these ill-structured problem scenarios with an instrument called the “Problem Scenario Evaluation Form”. This form was developed by the researcher on the basis of a literature review of ill-structured problems. This form consisted of two sections containing elements on the general and structural characteristics of the problem scenarios. The data were obtained via a five-point Likert-type scale in which participants could set their preferences by marking the options from totally disagree to totally agree. After the form was made ready, it was examined by two experts in the field of IT and necessary changes were made according to the suggestions of these experts.

In the first part of the form, there were four general arguments about the problem scenario. One of these general arguments was about the comprehensibility of the problem scenario. The others concerned the suitability of the problem scenario for the selected subjects, the objectives of these subjects and the cognitive level of the students. In the second part, there were 11 arguments that emerged from the literature review on the features of ill-structured problems. Five of these arguments were about the nature of the problem structure and the remaining arguments were about the nature of the task environment. The participants’ options for arguments in these two parts of the instrument were collected on the basis of a 5-point Likert type scale. The options of this scale were “totally agree, agree, neutral, disagree and totally disagree”. In order to analyze these parts, the average points of responses were calculated by giving totally agree 5 points, agree 4, neutral 3, disagree 2, and totally disagree 1 point. In addition, the last part of the form contained an open-ended question, which examines the intended changes made to the scenario by the reviewer. The example form is located in Appendix F.

Science Achievement Test

The researcher adapted an academic achievement test of science subjects for the activities (please see in Appendix R). In the process of adaptation of this test, a table of specifications based on Bloom's Taxonomy was prepared for the selected activities in line with topics in science, since the alignment of questions and goals is crucial for achievement tests. In the selected activities, the subjects were (1) Physical Events and (2) Creatures and Life in Science Course. In addition, the related units for these subjects were listed as Propagation of Light, Incoming Beam, Reflected Beam, Surface Normal, Human and Environment, Environmental Pollution, Environmental Protection and Beautification, Human Environment Interaction, Local and Global Environmental Problems**,** Human and Environment, Disruptive Nature Events and Protection, Measurement of Force and Friction, Applications of Friction Force on Slippery and Rough Surfaces, Applications of Friction Force in Daily Life in the course curriculum. The objectives for those subjects and units were also derived from the same curriculum defined by the Board of Education and Discipline.

A question pool for selected objectives was developed with 26 multiple-choice questions chosen from the content of the official platforms (MEB Ölçme, Değerlendirme ve Sınav Hizmetleri Genel Müdürlüğü (ÖDSGM) and Eğitim Bilişim Ağı (EBA)) of the Ministry of National Education. A review of these questions was carried out by an expert in the field. In addition, two science teachers assessed these questions with the Science Achievement Test Evaluation Form (please see in Appendix G) to ensure content validity of the test. In the assessment form, three options for each question were provided to the teachers: appropriate, must be corrected, and must be excluded. According to the results of this assessment, 3 questions were excluded from the test and 6 questions were modified on the basis of the opinions of the science teachers. During this assessment, teachers were also asked to put the questions on the table of specification which was prepared based on the objectives of related science subjects. The final version of this table of specification including the number of questions in the instrument was presented in Table 3.6.

Table 3.6 Table of Specifications for Science Achievement Test

Objectives	Knowledge	Comprehension	Application	Analysis
1. Give examples of friction force from daily life.		1,2,3		
2. Explain the role of friction force in life with examples and experiments.			4,5	
3. Shows that the light coming from a source follows a linear path in every direction by drawing it.			6,7	
4. Explain the relationship between the incident beam, reflected beam and surface normal.		9,10,11		
5. Explain the positive and negative effects of lighting in daily life.			13	12
6. Classify the items according to their transmission of light feature.	14	15	16	
7. Express the importance of interaction between human and environment.		17,18		
8. Provide suggestions for the solution of an environmental problem in the immediate vicinity or in the country.				19,20
9. Explain the destructive nature events caused by natural processes.			22,23	
10. Express the ways of protection from destructive natural events.			25,26	

After the elimination of the redundant items (question 8, 21, and 24) and necessary modifications made on the test, two 6th grade students were assigned to the pre-pilot investigation of the test items. These students were interviewed on the test items while they were answering the questions individually. The interview protocol (please see Appendix H) contained questions about the comprehensibility of test items. Students were also asked to provide their reasons for choosing that option and how they eliminated the other options during this testing process. The results of these interviews showed that two students had answered all the questions on the test. They had wrong answers for the different questions but they did not report any unclear points on any questions. Therefore, the researcher did not make any changes to this version of the test. In addition, the duration of the test was calculated in this testing process. It was determined to be 25 minutes for 23 multiple-choice questions with four options.

In the pilot study, the achievement test was applied to 132 6th grade students in a public school to carry out an item analysis of the test. In order to calculate the difficulty and discrimination levels of the questions and the reliability of the test, the true answers of each students were coded as 1 and false answers as 0 using SPSS statistical software. The students' scores were ranked from the highest to the lowest in Microsoft Office Excel and the supergroup and subgroup were identified using the critical value of 27 per cent. Then, the formula of $r_{jx} = D_{sup} - D_{sub}/\,(n_{sup} + n_{sub})$ / 2 and the formula of $p_i = \; = D_{sup} + D_{sub}/\; n_{sup} + n_{sub}$ were used to determine the discrimination indices and difficulty level of test items, respectively. The results of these calculations are given in Table 3.7 with the test items.

Table 3.7 Item Analysis Results of the Achievement Test

Questions	p_i	r_{jx}	p_i **Interpretation**	r_{jx} **Interpretation**
Q1	0,49	0,45	Moderate	Ideal
Q2	0,71	0,53	Easy	Ideal
Q3	0,68	0,47	Easy	Ideal
Q4	0,45	0,47	Moderate	Ideal
Q5	**0,87**	**0,21**	**Too easy**	**Low**
Q6	0,71	0,42	Easy	Ideal
Q7	0,63	0,42	Easy	Ideal
Q8	0,74	0,32	Easy	Normal
Q9	**0,45**	**0,26**	**Moderate**	**Low**
Q10	0,42	0,42	Moderate	Ideal
Q11	0,51	0,50	Moderate	Ideal
Q12	0,50	0,53	Moderate	Ideal
Q13	0,45	0,53	Moderate	Ideal
Q14	0,62	0,61	Easy	Ideal
Q15	0,63	0,58	Easy	Ideal
Q16	0,71	0,47	Easy	Ideal
Q17	0,50	0,53	Moderate	Ideal

Table 3.7 (cont'd)

Q18	0,59	0,61	Moderate	Ideal
Q19	0,62	0,45	Easy	Ideal
Q20	0,63	0,42	Easy	Ideal
Q21	0,79	0,37	Easy	Normal
Q22	0,79	0,32	Easy	Normal
Q23	0,61	0,58	Easy	Ideal

Criteria and cutoff points for discrimination indices and difficulty levels of test items are determined by Baykul (2000). Those values and decisions on them are given in Table 3.8.

Table 3.8 Cutoff points for Discrimination Indices and Difficulty Level

	Value	**Interpretation**
p_i **Difficulty Level**	.00 - .19	Too difficult
	.20 - .39	Difficult
	.40 - .59	Moderately difficult
	.60 - .79	Easy
	.80 - .99	Too easy
r_{jx} **Discrimination Indices**	.00 -.19	Too low (needs to be removed)
	.20 - .29	Low (needs to be revised)
	.30 - .39	Normal (can be used)
	.40 - .99	Ideal (should be used)

(Adapted from Baykul, 2000)

According to Baykul (2000), the level of difficulty for an item is too difficult if the item difficulty index (pj) is between 0.00-0.19. If this value is between 0.20-0.39, it means the item is difficult. Moreover, when it is between 0.40-0.59, the item has medium difficulty. Pj between 0.60-0.79 means the item is easy and if it is between 0.80-1.00 the item is too easy. Based on these cutoff points, one of the questions, Q5 was found to be too easy, 13 questions were easy, and the remaining questions had a level of moderate difficulty in the piloted science achievement test.

For the choice of questions on the basis of item distinctiveness indexes (rjx), cut-off points between 0-1 were used in the item analysis. According to Baykul (2000), the item is considered unacceptable if r_{jx} < 0.20, and should be revised since the distinctiveness index is low if r_{jx} is between 0.20 and 0.29. The index is considered normal and the item can be used if its value is between 0.30 and 0.39. Additionally, the ideal items are those which have discrimination indices above 0.40. In the Science Achievement Test of the current study, only three of the test items had normal discrimination indices and so were considered acceptable. However, since the distinctiveness indices were calculated as low for items Q5 and Q9, they were removed from the test. The remaining items in the test had ideal discrimination indices. Therefore, they kept their place in the final version of achievement test.

After the exclusion of unacceptable test items, the arithmetic mean, standard deviation, variance, difficulty, and reliability calculations of 21 items were conducted for the achievement test. According to the results of these calculations, the Cronbach's Alpha level was found to be .81 with a score range of 2 at minimum to a maximum of 20. The mean was 12.99 and the standard deviation was 4.4 with -0.28 skewness and -0.74 kurtosis values. In addition, the average difficulty level was found as .61, which is an acceptable value for the achievement tests.

Unplugged Algorithm Quiz

The researcher prepared an instrument called the Unplugged Algorithm Quiz (please see in Appendix S) to evaluate the academic achievements of students on the subject of algorithm in the ITS Course. The development of this instrument began with the creation of a table of specification based on the curriculum established by the Board of Education and Discipline. The related subject of activities for the algorithm quiz in this course was "Programming" in the "Problem Solving and Programming" unit according to this official curriculum. The table of specification for this instrument is given in Table 3.9. After the creation of this table, seven open-ended questions were developed by the researcher. These questions were modified by taking into account the review of two IT experts. The course teacher also reviewed the quiz questions and the corresponding table of specification.

Table 3.9 Table of Specifications for Unplugged Algorithm Quiz

Objectives	Comprehension	Application	Analysis	Synthesis
1. Develops algorithms to solve a problem.				All (except4)
2. Explains flow chart components and functions.	4			
3. Draws the flowchart for an algorithm.		5		
4. Extracts errors by testing an algorithm.			3	
5. Develop algorithms using linear logic structure.				2
6. Develop algorithms containing decision structures.				6
7. Creates algorithms with loop structure.				7

Two sixth grade students at the public school piloted the prepared quiz separately in order to identify the needs for improvements on the test. During the students' performance, several questions were asked to them about the questions on the quiz based on the interview protocol as shown in Appendix I. This protocol involved questions about the comprehensibility of the test items. The students were also asked their reasons for choosing that response and the reason for eliminating other options, in accordance with this protocol. The results of the pilot administration of the quiz indicated a number of modifications on the items. These modifications were made and the final version of the Unplugged Algorithm Quiz was completed before the implementation process.

The quiz included open-ended questions, therefore the researcher developed a rubric for the evaluation of the students' answers on this test. This rubric (please see in Appendix J) was reviewed by the course teacher and used to ensure the reliability of the assessment during the implementation process.

Activity Sheets

An activity sheet was developed by the researcher before the implementation process. This sheet presented a problem statement to the students at the top of the page. The following seven parts scaffolded them during the process of solving the ill-structured problem. Specifically, the first and second sections included questions about students' understandings of the problem. These sections, therefore, allowed students to articulate their own problem spaces in a group working environment. Their collaboration on and discussion of problem spaces remained in the third section as it contained a fishbone that can be filled with the problem's main and sub-reasons. Students could identify alternative perspectives of the problem statement with the help of this section, and they might construct multiple problem spaces. After their problem space/spaces were sufficiently built up, they were able to talk about possible problem solutions in the next two sections of the activity sheet. Requirements for the selected solution for robotic parts and stationery materials were requested in fifth, sixth and seventh sections. In the implementation section, students needed to prepare the algorithms necessary for the programming of robots. In the last section, students' predictions about their solutions were asked so that they had a chance to monitor their solutions by predicting the results. At the end of the activity sheet, there was a note that directs students to the programming phase of the activities.

The draft version of the activity sheet was reviewed by two experts in the field. After these revisions, a number of changes were made on it. One of these changes was the addition of a part in which students can write group names and group members. In addition, some changes were made on the expressions in the sections. For example, the original question and instruction in the first part of the sheet, “What do you understand from the above question? Write what is explained in the question” was changed to “What do you understand from the above-mentioned problem? Write down what is explained in your own words in the space on the side of the problem”. Similarly, the original expression in the fourth section of the activity sheet was “What is your solution proposal for the question above? Write your solution proposal in the space on the side”. This expression was modified to “What are your solution proposals for the above problem? Please write down your solution proposals in the space on the side. You should try to find more than one solution”. Moreover, one of the experts suggested that some phrases on the sheet be highlighted. These items were negative phrases such as “that you do not plan to use” and phrases showing restrictions such as "in your own words" used in several sections. Accordingly, these phases were modified as underlined in the activity sheet.

Another modification was the requirement of a new section on the activity sheet for the selected solution revealed during the implementation process. This section was added between the fourth and fifth sections. The final version of the activity sheet therefore was presented in Appendix K. In addition to its main purpose of providing guidance to students during the activity process, this activity sheet was also used as a supporting data source during the data analysis phase of the current study. When necessary, the answers provided by the student groups in the sections of the activity sheet were used for the further explanation of the findings.

Reflective Dairy and Drawings

On the basis of the recommendations made by the members of the thesis monitoring committee, an additional instrument named the Reflective Diary and Drawings was used in the second cycle of the implementation. The reason behind the need for this additional tool was that classes were much more crowded in the second cycle than the first one. In order to reach the views of all students in these crowded groups, the researcher developed this supportive data collection tool. There was a drawing area in the first section of this instrument. In this section, students were asked to draw the activity time. They were also required to support their drawings with text as answers to several reflective questions about the activity time in this section. The main purpose of the drawing section was to remind students of the activity time. In the second section, a reflective essay on the activity was requested. A number of questions about students' experiences, opinions and feelings about the activity were given at the top of this essay area to guide students about the content of the essay.

Following the development of this instrument, two experts reviewed it in the field of IT and the researcher made modifications to it on the basis of experts' suggestions. A linguist also checked the instrument to ensure the clarity of voice in it. After these revisions, the last version of the instrument became ready (Appendix L). At each activity this form was given to the students and they were asked to fill it out on a voluntary basis before the next activity. As a result, a total of 83 completed reflective diaries were collected throughout the second cycle of the implementation process.

3.4.3 Observations

In order to obtain information on the characteristics of the target group and the learning environment, the researcher took part in the lessons of the students studying robotics programming during the ITS Course hours and observed the learning environment by taking notes without any form. Another aim of this unstructured observation was to get acquainted with the students, since both the research itself and the researcher were novel to the students. The data collected from these pre-study observations were typed by the researcher at the time of the observation. The duration of these observations was 6 weeks for the first cycle and 4 weeks for the second cycle of the study.

In addition, the researcher's observations during the implementation of the activities were used as supporting data for the study findings. The observation form was developed for these structured observations prior to the implementation process, but since the researcher was extremely active during the activities, the form could not be filled out timely. Instead, recalled observation data were used when required during the data analysis process.

3.5 Overall Research Process

In the course of the current study, the steps in the process of formative case research expressed by Reigeluth and Frick (1999) were taken as follows:

1. Create a case to help you generate the design theory.
2. Collect and analyze formative data on the instance.
3. Revise the instance.

4. Repeat the data collection and revision cycle.

5. Fully develop your tentative theory.

The overall research process is illustrated in Figure 3.1 and elaborated below.

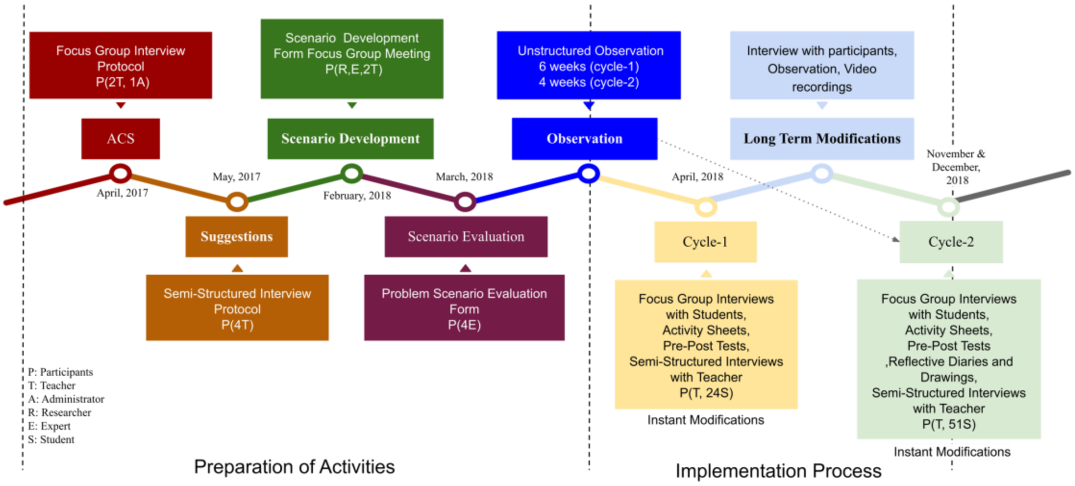

Figure 3.1 The Overall Reseach Process

Step 1: Create a Case to Help You Generate the Design Theory

Analysis of Current Status

In the current study, an analysis was used to learn about the nature of the implementation school and make a decision on the proposed problem-solving activities at the beginning of the study. A focus group meeting was held at the implementation school for this analysis, which was inspired by another technique called SWOT analysis. According to Osita, Onyebuchi and Nzekwe (2014), the SWOT analysis is one of the various strategic tools used to ensure that the intervention objective is clear and well-defined, identifying and addressing both positive and negative factors with potential impacts on the effort. This technique involves examining strengths, weaknesses, opportunities, and threats for an intervention (Harrison, 2010).

A presentation was prepared to introduce the study and the research objectives to the participants at the focus group meeting for this anaysis. This meeting was held at the first implementation school with the participation of two teachers (from the field of IT and science education) and an administrator (from the field of design and technology). After the collection of the data in the meeting using a voice recording, the transcription of the focus group meeting recording was performed by the researcher to gather the codes and categories. Based on the findings of the analysis of the current status, there were some directive insights about the activities to guide the development of them.

Development of Problem-Solving Activities

Suggestions for Activities

In order to develop the activities, the first objective was to gather the suggestions of the science teachers who had previously experienced the robot kit tool in the learning environments. Semi-structured interviews were conducted with three science teachers, one by one on remote phone calls. An additional science teacher preferred to respond to the interview questions in writing. Therefore, the responses from this participant were taken via e-mail. The general purpose of the data collection here was to take advantage of the experience of those teachers who had used these tools before and to get their suggestions for the proposed problem-solving activities.

Preparation of Activity Sheets

The researcher has developed an activity sheet aimed at encouraging students to follow the problem-solving process during the activities. The theoretical framework for research described in the previous chapter has contributed to the development of this sheet. Briefly, the Instructional Design for Ill-Structured Problems (Jonassen, 1997) was used to identify the steps of the ill-structured problem solving process in the activity sheet. Nelson (1999) has introduced another framework chosen for the current study, Collaborative Problem Solving (CPS). Specifically, CPS explains instructional strategies for the collaborative problem-solving process. The sheet therefore included instructions to encourage students to work together in their groups during the activity time.

Preparation of Activity Scenarios

Seven problem scenarios were developed in a focus group meeting with teachers and experts (two of them from the field of IT and others were from science). The suggestions of the experts in the previous phase formed the basis of this meeting. Additionally, the objectives of both courses (science and ITS) were shared with the participants prior to the meeting. Problem scenarios were proposed with their subjects in science, objectives in both science and ITS, activity name, and the required equipment for the solution of the problem. The researcher noted the details of the scenarios on a form during the meeting. One of the completed forms is given in Appendix E. Additionally, the details about these activities are given in the results part of the current study.

At another meeting, these seven scenarios have been reviewed and upgraded with an IT expert. These upgrades were mainly on the statements of problem scenarios to make them more authentic with real-life narratives. The notes taken during the meeting about these upgrades were applied on activity sheets by the researcher before the assessment of activity scenarios. For instance, one of these scenarios in the draft version was "People sunbathing on the beach are damaged from this activity and they get various diseases when the angle of arrival of the sun's rays gets steep. Is it possible to design a robot that can help people in this situation?". To make it more authentic before the assessment, it was updated to "People who sunbathe on the beach in the summer are often damaged by the sun rays, especially at noon, as they do not notice the angle of arrival sun rays. This situation creates undesirable conditions such as sunburn, as well as inviting many diseases, especially skin diseases. What can our robots do to protect people from this situation? How do you design a robot that can protect people from the harmful effects of the sun on the beach?".

Assessment of Activity Scenarios

As conducting all seven activities takes a significant amount of time, it was necessary to eliminate some of them before the implementation process. Furthermore, it was important to obtain extra expert views on these activity scenarios derived from ill-structured problems. Therefore, four field experts differing from the developer group reviewed the scenarios with a tool called the "Problem Scenario Evaluation Form" (see Appendix F). This form consisted of two sections that contain items about the general characteristics and structured level of the problem scenarios. The activities ordered according to their structure level based on the data obtained through a five-point Likert scale with this form. The results of these examinations were given in the findings section of the current study.

Some of the problem scenarios were eliminated based on the subject distribution and total general points on the evaluation form. Some of the modifications were applied based on the suggestions of these experts, which were placed in the last part of the form. For example, one of the experts stated that giving a detail like the beach in the lifeguard activity limits the structure of this problem. Therefore, they said, this detail should be removed from the scenario of the problem. As a result, the scenario for the lifeguard robot was modified to “There is nothing like spending time outside on bright sunny days. In addition to making you feel good, sun rays that contain ultraviolet (UV) rays are our most important natural source for the synthesis of vitamin D which we need for bone development. Contrary to this positive feature, when we are exposed to sunlight more than necessary, we may encounter many undesirable results, especially sunburn. In addition, this situation invites some skin diseases. What can our robots do to protect people from this situation? How can we design a robot that can help protect people from the harmful effects of sunlight?”. One of the other experts argued that that the name of this activity may have a directive effect on students. As a result, the name of the activity changed to “The robot that protects from harmful effects of the sun" for this scenario.

After these modifications, two linguists also reviewed the selected activity scenarios in activity sheets and their language corrections were carried out prior to the implementation process. For instance, after their revision the scenario of the aforementioned activity was finalized as “There is nothing like spending time outside on bright sunny days. In addition to making you feel good, sun rays are our most important natural source for the vitamin D we need especially for bone development. Contrary to this positive feature, when we are exposed to sunlight more than necessary, we may encounter many undesirable results, especially sunburn. In addition, this situation causes some skin diseases. What can our robots do to protect people from this situation? How can we design a robot that can help protect people from the harmful effects of sunlight?”

Design of Activities

As an ill-structured problem-solving process requires important domain knowledge, the activities were scheduled considering the necessary issues in both Science and ITS Courses. As a result, they were planned to be conducted in the spring semester in the first cycle, since the problem scenarios included only the science subjects of the fall semester. In addition, problem solving and programming subjects had to be completed within the ITS course. Therefore, these topics were expected to be covered in this semester. These subjects were taught over the robot kits used in the implementation of the current study. In this process, the researcher merely observed the learning environment, both in order to get familiar with the students and to learn about the implementation environment.

The results of these observations indicated that the lectures normally consisted of three parts, including beginning, activity and closure parts. Some of the results of these observations at the beginning of the implementation process influenced the design of the activities. Therefore, while some observation results collected before the first cycle of the implementation are given in Table 3.10 below, it is also possible to find all the results of the observations for both cycles in the findings section of the current study. The parts of the general course hours based on the observations were given in the first section of this table. In addition, the results of the notes taken during the observation were accumulated on the basis of those parts in the observations section. Lastly, the decisions on the design of the activities on the basis of those observations were set out in the last section.

Table 3.10 Observation Results for the Design of Activities

Parts	Observations	Decision for Activities
Beginning	• The students take responsibility. • Lessons generally start with reminders of previous topics and continue to be informed of the goals. • The question and answer method is used effectively. • The teacher is willing to use real-life examples to bring students to the attention of the subject, and students usually responded positively to these examples.	○ A preliminary discussion about the problem at the beginning of the activity may be necessary (to remind the goal) ○ The students are familiar with real-life problems used for the authentic scenario of the ill-structured problem in the activities.
Activity	• The students know the general problem-solving stages. • The problem situation could easily be imagined by them. • They could argue several alternatives and creative solution proposals to the problem while they were using the fishbone technique. • The teacher preferred to use brainstorming to trigger the argumentation skills of students in several parts of the activity. • The use of the resources in the classroom was very high. • In activities the students usually work individually. • They are highly active in the activity process and willing to ask the teacher questions.	○ Students know general problems but may need guidance in following the ill-structured problem-solving procedure used in an unfamiliar activity. ○ Students can easily imagine authentic problems, reach the causes of this problem using techniques such as fishbone, and offer them creative solutions in activities. ○ Various resources can be brought to the classroom for the activities. ○ The teacher may need to help the students during the activities, communication between teacher and student will facilitate this guidance. ○ Since students are not doing group work, a group work should be organized before the activities and group work should be encouraged during the activities.
Closure	• With the students, the summary of the subject is done through the use of the question-answer method. • If the activity is not finished until the bell rings, the homework will be addressed. The bell is a critical stimulant, however since students usually do not wait any longer when it rings once.	○ The students should be given the opportunity to summarize the topic at the end of each activity. ○ Homework can be given if it is not over in time. ○ As the bell is an important stimulus for students, activities should not be extended and should be completed on time

In addition to all these decisions, each activity of the first cycle was designed to cover four course hours. According to the experts' view and research framework, students would have encountered the problem scenario on the activity sheet in the first part and they could begin to solve the ill-structured problem by filling out this activity sheet. In the next section, they would continue to develop their solutions by programming the robots. In the last section, they would enter a design and production phase by using stationery materials to reveal their solutions with their programmed robots.

Materials

Four available robotic kits were compared on the basis of a number of characteristics by the researcher and the teacher prior to the implementation process in order to find the most appropriate robotic tool for the investigation. While making this comparison, issues such as the number of robot parts, the difficulty of joining the parts, the type of connection, the simplicity and language support of the programming editor used, availability of technical support, and price were important factors in the decision-making process. The full version of this comparison is presented in Appendix M. Ultimately, O-bot Kit was selected among the alternatives for the current study.

O-bot Kit

Robotsan (Robotics and Mechatronics Technology Ltd.) has introduced a robotic kit, which was the first programmable educational robotic produced with domestic capital in the country. The project was also supported by TÜBİTAK (Scientific and Technological Research Council of Turkey) to develop K-12 students' algorithm and visual programming skills. The kit included the components of O-bot (ER), idea (visual programming editor) and iDea-Sim (Simulator). These components were presented in the following section.

O-Bot

O-bot is a mobile tangible robotic kit that can be easily set up and programmed by K-12 students. The complete package of the robot kit consists of two load bearing panels, a control card, a voice card, two optical sensors, two photo sensors, a proximity sensor, a temperature sensor, a micro switch, a led, a buzzer, battery pack, cables, two DC motors and two tires. This kit is illustrated in Figure 3-2

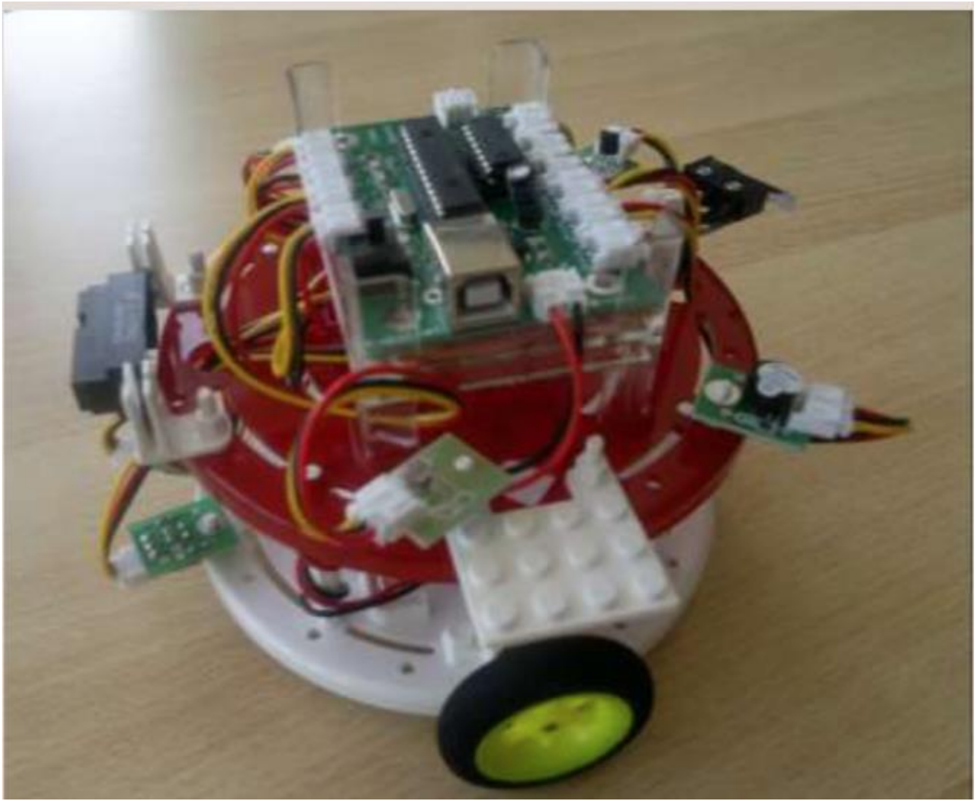

Figure 3-2 O-Bot Robot Kit

iDea

iDea (Integrated Development Environment for Applications) is a flowchart-based programming editor used for O-Bot programming. This software was designed as both a professional syntax-based programming editor and a visual programming editor to make robot programming easier for K-12 students. Users can therefore effectively control the card on the robot by using iDea flowcharts and control panel items in the editor. The software can be used in both English and Turkish. The interface of the editor and a ready flowchart in it are shown in Figure 3-3.

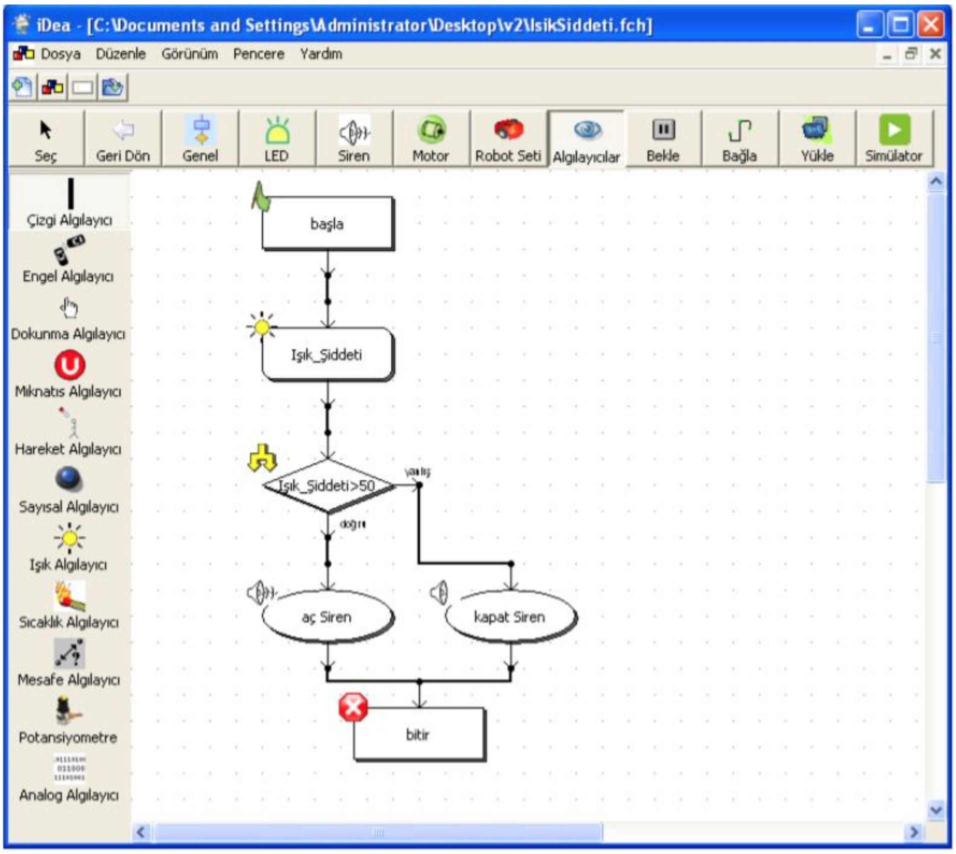

Figure 3-3 iDea Programming Editor

iDea-Sim

iDea-Sim is a 3D simulator that was launched later from the introduction of the other components of the kit by the company. In this simulator, a virtual robot moves in an environment that is very close to the law of the real world of physics. This environment is enriched by line, endpoint, obstacle, and light source tools that are the most common tools for robotic real-world activities. The interface of the simulator is illustrated in Figure 3-4.

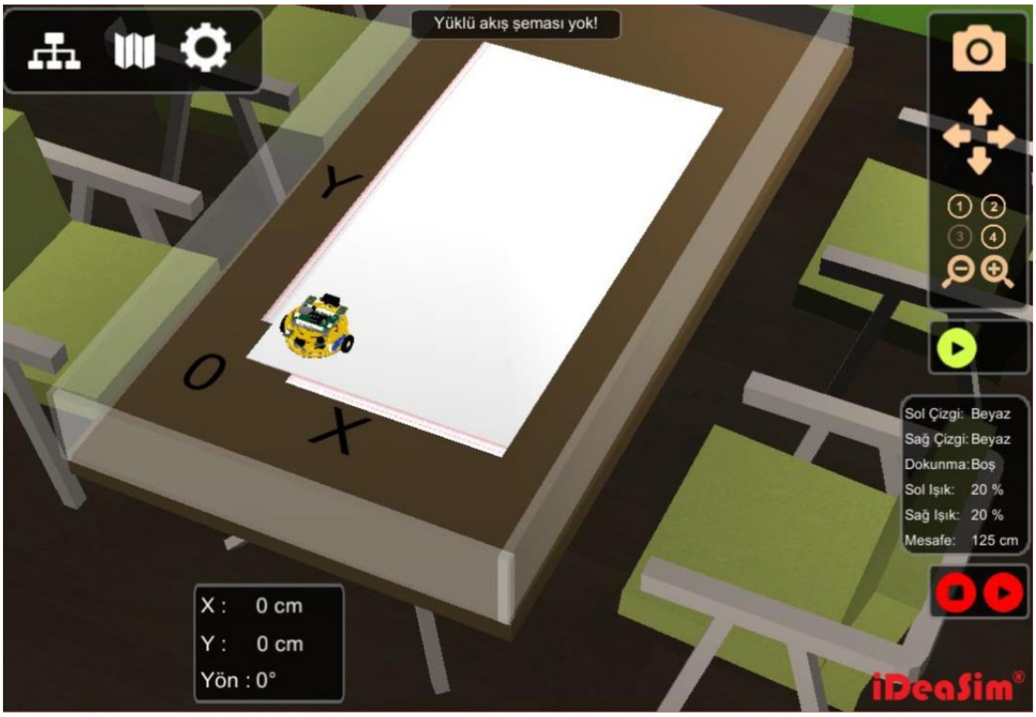

Figure 3-4 The Interface of iDea-Sim

Step 2: Collect and Analyze Formative Data on the Instance:

After the instance was created, the first cycle implementation process was carried out with four activities named Robot Factory, Lifeguard Robot, Savior Robot, and Scavenger Robot, respectively. Focus group meetings with students who worked collaboratively in the groups were held to gather data to form the instance itself. In addition, after each activity, the teacher was also interviewed for the same purpose. Other supporting data sources for this cycle were the researcher's observations and activity sheets of the groups. Moreover, each activity process was also recorded by a video recording device. However, as students were freely moving during the activities and the environment was very noisy, it was not possible to use these recordings efficiently during the analysis of the data.

Step 3: Revise the Instance:

The revision of the instance was carried out with a number of modifications based on the collected data both during the implementation process and after the completion of the first cycle. For instance, the instant modifications were the changes on the activities, which were made for the following activities during the implementation process. These changes were applied on the activities as a result of consensus between the researcher and the teacher. In addition to these immediate changes, the long-term modifications were also applied on the activities and the implementation process of the instance between the cycles. These long-term changes stemmed from the analysis of the data gathered from the interviews of the participants and video recordings. All these modifications were reported in the findings chapter of the current study.

Step 4: Repeat the Data Collection and Revision Cycle:

In the second cycle of the study, data collection processes were repeated using both the same methods of the first cycle and an additional tool which was suggested by the thesis monitoring committee after the first cycle. This instrument was a reflective diary that included a number of trigger questions about the activity process and a section for students to draw on the activity time. In addition, the practice of immediate modifications to the activities continued during the implementation process as in the first cycle.

Step 5: Fully Develop Your Tentative Theory:

The data collected during the preparation and implementation process of the activities were analyzed in order to answer the research questions and the results were given in the findings chapter. One of these research questions addressed the guideline for ill-structured problem solving activities used in the current study. As a result, this guideline emerged as one of the tentative theories for similar activities in the field.

3.6 Data Analysis

Qualitative data were collected through interviews, documents, and observations in the current study. The analysis of the data from these sources was performed utilizing the six-step approach identified by Creswell (2012). These six steps were: preparing and organizing data, exploring and coding them, describing and forming themes, representing of findings through narratives, interpreting and validating the findings respectively. According to Babbie (2007), exploring and coding data steps can be elaborated into three procedures of open coding, axial coding and selective coding. As an initial process, data can be classified and labeled in the open coding step. By grouping these codes, core concepts can be identified in the axial coding process. In the selective coding step of the analysis, the aim of the researcher should be to choose the central code that organizes the other codes delivered from the axial coding process. Using these steps, the qualitative data were analyzed with the help of MAXQDA software to address the research questions of the study.

The voice records in the interviews were transcribed during the preparation phase of data. In addition, the documents were scanned in this phase to be added into the software. The organization of these data was carried out by putting them in folders named with their sources in the software. Transcribed text and scanned documents were generally examined at the beginning of the open coding phase. During this step, some notes were taken to look at the general structure of the data. The data were then re-examined in detail to identify the codes with the terms referring them. After the completion of the open coding phase, the generated codes were grouped in more general terms defined as categories of the data set in the axial coding process. In the next step, the categories with common points were combined to create the themes of the study. Following this coding and grouping process, a comprehensive report was drawn up representing the findings for the research questions of the current study. In addition, the relationships between the generated codes and categories were used to develop the guideline of the activities for the last research question.

For quantitative data, SPSS software was used to analyze data provided by participants who applied Scenario Evaluation Form, Science Achievement Test, and Unplugged Algorithm Quiz. This software was first used to identify the descriptive statistics of these data. In addition, inferential statistics were used to compare the data of groups of students who performed the test and the quiz during the implementation process.

3.7 Quality of Findings

3.7.1 Validation Perspective

The validity refers to the appropriateness, meaningfulness and usefulness of researchers' inferences made on the basis of data collected throughout the qualitative research process (Fraenkel, Wallen, & Hyun, 2011). According to Creswell (2007), the validation of findings is based on certain strategies that can be used to ensure the accuracy and credibility of qualitative research findings. Although the number of available strategies used to validate the findings is quite high, the suggestion is that "qualitative researchers engage in at least two of them in any given study" (p.209). As a result, some of these strategies were employed to eliminate possible validity threats for the findings in the current study.

One of the strategies, triangulation, requires the use of multiple data sources for evidence from different individuals, types of data, and methods of data collection (Creswell, 2007). Accordingly, data on the findings of the preparation of the activities were collected from practitioners and experts from different fields. The fact that these participants had different lengths of experience was also important for the triangulation of the findings in this part of the study. In addition, data were collected from both the teacher and students with semi-structured interviews during the implementation process. Additional sources of data such as student documents and research observations were also used during the disclosure of the findings. Moreover, some qualitative findings were supported with quantitative data. As a result, it was clear that the data triangulation was provided with different participants and types of data to ensure the validity of the findings in the current study.

The data collection instruments were prepared by taking the literature into consideration. Specifically, the framework of the study shed light on the preparation of these tools. Additionally, the interview questions were formed on the basis of literature in the technology integration, problem-solving, and formative research fields. The construction of all these tools and the whole research process were consulted by an expert in the field which refers to external audits strategy. According to Creswell (2007), this strategy requires an external view to examine both the process and the product of the study closely. This view can be done with other researchers from outside of the study and is called peer debriefing (Fraenkel et al., 2011). Although no peers have followed the entire process of this study, findings have been shared with some colleagues from time to time and a consensus on the findings has been sought during these meetings. In addition, the transcriptions were coded more than once in different times by the researcher to ensure the consistency of the findings. Moreover, this data analysis process was reviewed by an expert in the field and the codes, categories, and themes that emerged as findings were presented to the committee members of the research prior to their reporting.

The researchers need to check the accuracy of the data with the participants of the research (Creswell, 2012). Member check was only applicable for the interviews with practitioners, experts, and the teacher during the implementation process. The students were interviewed at focus group meetings. Due to the young age of the students and the fact that the interviews are carried out at group meetings, the transcribed data could not be sent to student participants for validation. However, the transcripts of other interviews were sent to remaining participants by e-mail for them to check.

3.7.2 Reliability Perspective

Reliability is generally known as the similarity of findings when conducting the same or similar research. This however, contradicts with the fundamental principles of qualitative research. According to these principles, qualitative research reveals the findings according to the environment and people involved in the research process. Therefore, it reaches results that cannot be repeated with others (Yıldırım & Şimşek, 2011). According to Cohen, Manion and Morrison (2007), the nature of qualitative studies includes the uniqueness of the situation, which should be accepted as a strength rather than weakness. Accordingly, seeking reliability in qualitative research should be avoided (Levis & Ritchie, 2003). According to another view, the reliability perspective of any qualitative study can be examined according to the trustworthiness of the findings. According to Creswell (2007), employing a high quality of recordings, verbal data transcriptions, and inter-coder agreements are the ways used to enhance this trustworthiness in qualitative studies.

In order to increase the reliability or trustworthiness of the qualitative data of the current study, the interviews with the participants were recorded by a voice recorder. Although there were overlapping voices in some of the focus group meeting recordings, the quality of these recordings was generally quite good. In addition, these voice recordings were transcribed by the researcher prior to their analysis. Finally, after the researcher's analysis, approximately 10% of the transcribed data was shared with an inter-coder in the field of IT. This inter-coder analyzed the raw data by coding it before the meeting with the researcher. At this meeting two coders discussed the similarities and differences of codes and tried to reach a consensus, and an inter-coder agreement was reached between these researchers at the end of the meeting.

Inter-rater reliability was also applied for the scores of the students on the Unplugged Algorithm Quiz since this instrument involved open-ended questions. The researcher and the teacher separately graded some of the students' quizzes independently. For this grading, 10 percent of quiz papers of students were selected randomly and the scores of these inter-raters were compared with SPSS software. The result of the inter-rater analysis based on Intraclass Correlation Coefficients estimates with mean-rating ($k = 2$), absolute-agreement, and 2-way mixed-effects model was equal to .98, which referred to an excellent agreement on the test scores for the raters.

3.8 Role of Researcher and Ethical Considerations

The role of the researcher is critical, particularly in qualitative research, as the researcher is the primary source of data collection and analysis processes (Merriam, 2009). In the data collection process of the current study, the researcher acted as the main instrument of the study by asking questions to the participants both during the development of the activities and implementation process of them. Additionally, the researcher was one of the facilitators during the implementation process. Firstly, he was the person who provided all the materials and equipment necessary for the students to carry out these activities. In addition to this, he took part in conducting the activities, just like the teacher during the implementation process. He answered students' questions during the activities, helped them whenever they needed, and guided them through the process. Moreover, the teacher had to leave the classroom due to an administrative task loaded on him during one of the activities. In this case, the researcher became the only authorized person to continue the activities for approximately 15-20 minutes period of that activity. In addition, while meeting student groups at the end of each activity, he tried to give them the confidence that the conversations in the interviews would not be shared with someone else, including their teachers. The purpose of this expression was to gain access to all the experience of students, whether good or bad, in the course of their activities.

Ethical principles were carefully taken into account throughout the research process. In the first place, research permission was obtained from the Committee on Human Ethics at METU (please see Appendix V) and the Ministry of Education. In addition, each participant was informed of the study purpose and the research process prior to the data collection process. The parents of students were also informed of the research and their consent was obtained with the help of a form before the implementation. The data collected from participants were not shared with others not related to the research and the names of the participants were kept confidential throughout the report of the current study.

CHAPTER 4

RESULTS

This chapter presents the findings of the current study. The results are reported in three subheadings, namely findings of preparation of activities, modifications on activities, and research question findings.

4.1 Findings for Preparation of Activities

In the current study, problem-solving activities for middle school students were developed in line with the content of ITS (Information Technologies and Software) and Science Courses. The objectives were chosen at the 5^{th} grade level for both courses. The subjects were associated with problem-solving and programming unit for ITS Course. In addition, they were related to physical events, creatures, and life units for the Science Course.

The preparation of the activities was based primarily on the literature review and results of several analyses. These results were reported below.

4.1.1 Analysis Result of Current Status for Problem Solving Activities

At the beginning of the study, an analysis was implemented to learn about the implementation school environment and make some decisions for the activities. The analysis was carried out with a focus group meeting. The demographic information of the sample volunteering to participate in that meeting was provided in Table 4.1. According to information gathered from the participants, one of them (A) was 30 years old, and he had a seven years of professional experience in the field of IT (Information Technology). The second participant (B) was a male science teacher who was 35 years old and had eleven years of professional experience in his field.

The last participant (C) was 29 years old. She was one of the administrators in the school and had eight years of professional experience in the field of technology and design.

Table 4.1 Demographic Information of the Participants in Analysis of Current Status for Problem Solving Activities

Participants	**Gender**	**Age**	**Field**	**Professional Experience/Year**
A	Male	30	Instructional Technology	7
B	Male	35	Science Education	11
C	Female	29	Administrator/ Technology and Design	8

After data collection, the transcription of the focus group interview was performed by the researcher to gather the codes and categories related to the themes of analysis named strengths, weaknesses, opportunities, and threats, respectively. A matrix of these themes with the related categories and codes was created to present the whole picture of the results and was presented in Table 4.2.

Table 4.2 Matrix for the Categories of Analysis of Current Status for Problem Solving Activities

Strengths/Categories & Codes	**Weaknesses/Categories** & Codes
Motivational Aspect • Increasing motivation • Increasing the interest • The sense of achievement **Cognitive Aspect** • Getting away from memorization • Making the subject memorable **Effects on Learning** • Eliminating the monotony • Learning by doing • Activating students • Improving learning • Allowing practice	**Financial** • Costing high • Inadequacy of robotics kits **Applicability** • Not applicable to all subjects

Table 4.2 (cont'd)

Individualization • Designing for own needs • Making something to ease the life • Creating own artifacts **Essence of Activities** • Being tangible • Suitable for other activities • Positive perception towards robotics • Positive effects on other students	
Opportunities/Categories & Codes	**Threats/Categories** & Codes
Technical • Technological infrastructure • Availability of computer laboratories • Adequate equipment • The simulator **Parental** • Willingness • Support • Relationship with teacher • Trust in the school **Regional** • The proximity of homes • Transportation • Advertising in province and district • Being close to companies **Educational** • Willingness • Interests • The classroom • The number of students • Prerequisite level • Non-intensive curriculum • Additional points in exams	**Duration** • Time-consuming • Limited time • Extra design phase • Extra course load • The schedule **Parental** • Not having support at home • Unavailability of time • Inadequate knowledge of IT **Instructional** • Low motivation level • Fear from courses • Fear of failure • Dislike the course • Worries about plagiarism • Students' readiness • Juniority • Attendance • Evaluation problem **External** • Physical conditions of the environment

Based on the codes of analysis, *strengths* of the activities were clustered within five categories such as motivational aspects, cognitive aspects, effects on learning, individualization, and the essence of activities. According to participants, the activities would increase the level of students' motivation and interest in the course. Students would also be satisfied since they would succeed in solving ill-structured problems in the activities. These codes were grouped into the *motivational aspect* of the strengths. Some of the strengths of the activities were related to the category of *cognitive aspect*. Getting away from memorization and making the subject memorable were underlined under the above-mentioned aspect. Based on the results, the activities would also have *effects on learning*. According to the participants, these activities might eliminate the monotony in courses and give them the opportunity for learning by doing. By enabling students to practise in the activities, they can improve the level of learning achievement. *Individualization* was one of the other strengths of the activities based on the analysis of data. According to participants, students would assume the productions as their own artifacts since the activities give them the opportunity to make designs according to their own needs and to design something that eases their life. The remaining strengths as being tangible and being suitable for the other activities were grouped under the category of the *essence of activities*. Additionally, the activities would not only change the perception of students participating in the activities towards robotics positively, but they also would have positive effects on other students from different classes, which were other features of activities related to the category of *the essence of activities*.

Only two categories emerged under the theme of *weaknesses* based on the data of the focus group meeting. According to participants, there was a financial obstacle of the activities. Since the prices of the robotic kits were quite high, there might not be enough kits for all students in the learning environment. *The applicability* of activities was the other weaknesses. Since the activities did not apply to all subjects, students would not have the chance to practise in all subjects using these problem-solving activities.

Four categories emerged in relation to the *opportunities* for the activities such as technical, parental, regional, and educational opportunities, respectively. According to the focus group interview data, the sufficiency of technological infrastructure constructed recently in the school, possessing adequate equipment in technology laboratory, and its' availability for students' use outside of lecture hours were codes of *technical* competencies. In addition to these competencies, the existence of the simulator in the programming editor of the robot kit, which made it possible to work at home, could be another technical opportunity that was related to the software itself. *Parental* opportunities of the activities were the family-related issues on the data of the interview. According to participants, the parents were willing to provide an excellent education for their children. In addition, there might also be a potential financial support from the parents who support similar activities. In addition to a good relationship between parents and teachers, the parents' trust in the school was also very high, all of which were the opportunities for the planned activities. Some opportunities were specifically named as *regional* opportunities. Students' homes were so close to the school that the transportation was effortless. The school also had some regional opportunities. First, it had a high-quality advertisement in the province and district. Second, thanks to its close the location to the companies developing similar projects and to the company that produced the robotics, there could be an opportunity to establish a connection with those companies if needed. The remaining opportunities were collected under the category of the *educational* opportunities. Based on data of focus group interview, the willingness of the majority of students in the classroom for implementation, their high interest in innovations, and their particular interest in computers were considered as motivational opportunities. The structure of the classroom as well as the number of students in the classroom were quite suitable for the activities. Other opportunities considered under the educational aspect were the high prerequisite level of students for implementation, and a non-intensive curriculum in the fifth-grade courses which made the implementation of such activities in that grade-level easier. Getting additional points in the TEOG exam (National High School Entrance Examination) with TÜBİTAK Projects might also provide an opportunity for the activities since same robot kits were used in these projects.

Codes for threats of the activities were classified into *duration*, *parental, instructional* and *external* categories. According to participants of the focus group, the activities were time-consuming, and the underlying reasons for this were the limited duration of the courses and the need for an extra design phase in them. This would not only pose a threat for the duration of the activities but also a treat for an increase in the course load. The weekly schedule of the course might also be a threat because it should be set depending on the activities. These issues were all the threats to the *duration* of the activities. The *parental* threats were mainly about the absence of family support at home for the students about the activities. Some families were seen by the participants as having the willingness for support but not having extra time to spend for them. Similarly, since some parents did not have adequate knowledge of ICT, they might not provide any support for the activities.

Based on the analysis of data from the focus group interview, the *instructional* threats were divided into two sections. One of them was named motivational threats. The codes of low motivation levels of students not interested in the course, their prejudices such as fears of failure and feeling strange for both courses, and their worries about plagiarism were grouped under the motivational threats. The other instructional threats of the activities were also revealed after the analysis of data. According to participants, some students' readiness may not occur at appropriate level. Since the entrance age of the students reduced five years ago in the national educational program, students could be at a low age at the fifth-grade level (low cognitive level) for the activities. The general decrease in the number of attendances in the spring semester was the other treat to the activities including the evaluation problem because of the difficulty of determining the level of learning within group works. The remaining code about the physical conditions of the school environment was about the security issues of the region and was considered as an *external* threat to the activities.

In conclusion, based on the findings of the analysis of the current status, there were some directive insights about the activities to guide the preparation of them. The results showed that there were strengths and opportunities for the activities to be developed for middle school students. Strengths about learning as well as motivational stregnts, cognitional strengths, and educational opportunities will be utilized to overcome the instructional threats such as low motivational level and attendance problems during the implementation. In the same vein, the technical opportunities will improve the settings of the activities. Although there will some parental risks ahead, the opportunities about the parents such as the relationship with the teacher can be used to overcome these threats. External threats should be taken into consideration during the implementation process since not all of them can only be defeated with the help of regional opportunities. In contrast to external threats, individualization and the essence of activities are the other strengths which will ease the activity process. Nevertheless, the financial weaknesses, the applicability of activities, and durational threats should be examined in further analysis.

4.1.2 Development of Activities

The opinions of the experts were collected through data collection procedures such as interviews and documents, and analyzed as a guide for the development of the proposed activities. The results of these analyses have been reported in three sections: *suggestions for activities*, *preparation of activity scenarios*, and *evaluation of activity scenarios.*

4.1.2.1 Suggestions for Activities

To develop the activities, it was primarily aimed to gather the suggestions of science teachers who had previous experiences about the tool, o-bot robot kits. Semi-structured interviews were conducted with four science teachers. The demographic information of all participants was presented in Table 4.3.

Table 4.3 Demographic Information of the Four Science Teachers Interviewed for Suggestions about Activities

Participant	Gender	Age	Professional Experience/Year	Experience of ERs in Courses
A	Male	30	6	Yes
B	Female	29	6	No
C	Female	28	4	Yes
D	Female	34	9	No

According to the results of the analysis, only one of these participants was male. All participants’ ages ranged from 28 to 34, and Participant D had the most professional experience in the field with nine years. According to their status showing whether they had previously utilized the robot kits in their courses, two of them stated that they had not used these kits in their courses previously. The reason behind this was the inappropriateness of the grade level of students for such activities in their courses. Participant B pointed out this issue in the interview as in the following:

> *Participant B: "No, I haven't had a chance like that. The reason is that I'm teaching 8th-grade students in the institution where teachers are fastened at this grade levels, so in the school posseses the logic of giving space to this kind of activity in other levels of grades. I haven't got such a chance since I get into the 8th grade."*

> *Participant B: "Hayır. Böyle bir şansım olmadı. Sebebi ise 8. Sınıf öğrencilerine ders veriyor olmam bulunduğum kurumda sınıf seviyelerinde öğretmenler kilitlenmiş durumda o nedenle diğer ara sınıflarda bu tarzdaki çalışmalar daha çok yer verilmesi mantığında okul. 8'lere girdiğim için de böyle bir şansım olamadı."*

Two participants used these robotic kits in their classrooms at *fifth grade level*. One of these participants selected friction force and electricity *subjects* in the activities because he/she thought that they were all physics subjects, and the robot kit had appropriate equipment and functions for those subjects. The other participant utilized robot kits in the sound and heat-temp subjects since he/she wanted to show students the application area of the courses in real life and to create better projects in those subjects. He/she also expressed that the equipment of the robot kits was particularly proper for those subject areas.

The preparation process of the activities was asked for these two participants. For one of the participants, this process started with the determination of the weekly subject. Then, he/she created the appropriate algorithm for the robotics. The other one started the process with the preparation of the equipment for the experiment. Then, he/she continued with the creation of algorithm diagrams for robotics, similar to the first one.

The activity process was also asked the teachers in a detailed manner. According to their responses, both participants started their activities by grabbing students' attention, but in different ways. One of them came to the classroom with the robot kit to motivate the students. Then, he/she continued with a short introduction of the kit. A question, "what can be done with the robot kits in the course?", was asked students to start brainstorming in the classroom. The introduction of the equipment of the experiment was the other step before the creation of the algorithm diagrams. The experiment was conducted at the end of the activity. The other participant began the activity by demonstrating readily-prepared project videos. In the next step, previously learned subject matter was recalled. Then, the required sensors on the robot kit were introduced. In the next step, the question of the activity was determined before the brainstorming period for the solution suggestions. As the last step, the algorithm was created and loaded on robots.

According to Participant A, there were several *positive sides* of his robotic activity. First of all, it was very interesting for students. The activity made it possible for the students to do something they had seen before. Additionally, it provided the decision that students could use these technology in daily life. For Participant C, activity's fixed and reliable measurement results were the most positive aspect. On the other hand, the *negative side* was the equality of opportunity which could not be attained because of the inadequate robotic kits for all students. For the negative sides, Participant A claimed that there were not any negative aspects of his activity. One of the remaining participants claimed that the only *obstacle* encountered during the activities were technical problems with computers. This issue was explained as follows:

> *Participant C: "The importance of computers used is very high. We sometimes had problems with the computers. Other than that, we had no problems. There is the idea-sim which we can see as a problem. The computers do not support idea-sim. Although we had installed according to the windows version of the computer, we had trouble. That was the only problem there. Other than that, there was no problem."*

Participant C: "Yaa problem olarak kullanılan bilgisayarların, ıı şey. Kullanılan bilgisayarın önemi çok. Bilgisayarlarda bazen problemler yaşadık. Onun dışında başka problem yaşamadık. Hani problem dediğimiz, idea-sim var, idea-sim'i desteklemeyen oldu. Bilgisayarların windowsunun versiyonuna göre yüklememize rağmen sıkıntı yaşadık. Hani bir sıkıntı orda yaşandı. Onun dışında bir sıkıntı yok."

As the solution process, this participant tried to overcome this problem by his/herself firstly but then got help from the IT teacher in the same school. The obstacle that the other participant encountered was about the observation of activity by students. This participant created small groups for the exhibition of the activity as a solution to this problem.

When these participants assessed the process of the activities from their *students' viewpoint*, one of them said that the students liked it, were satisfied with the activity, and wanted even to continue these kinds of activities later. The other one said that students found these activities entertaining and were willing to create the algorithms on their own.

Several questions about the activities proposed to prepare for this study were addressed in the remaining part of the interviews. One of these questions was about the suggestions of the participants for *the subject area* in science that would be covered in activities. Two of the participants thought that only the physic subjects were appropriate for the activities. They specifically suggested the subjects of heat and temp, light, sound since the sensors on the robotic kit were appropriate for these subjects, and the objectives in these subjects were more concrete and explicit for them. According to one of the participants, the activities could be conducted in all subject areas from biology to physics in science such as vitamins, livings, and environment, force and motion, and electricity. The last participant suggested that socio-scientific subjects could be covered in these activities such as environmental education, savings and renewable energy since he/she claimed that combination of both social and scientific subjects was essential to create awareness in schools, saying that

> *Participant D: "There is always a cliche for children such as science literacy. I think if we want the child to pick up garbage from the ground and throw it into the rubbish bin, or if we want it to be put in boxes according to the waste types, or if we want to cultivate a conscious society first, children should have more practice and experience on social-scientific fields."*

> *Participant D: "Hani çocukların hani hep böyle klişe bir şey vardır bilim okur-yazarlığı, fen okur-yazarlığı ıı mesela çocuğun yerden bir çöpü alıp çöp tenikesine atmasını istiyorsak ya da atık türlerine göre kutularına koymasını istiyorsak yani bu bilinçte farkındalıklı bir toplum yetiştirmek istiyorsak bence önce sosyo-bilimsel olarak alanlar üzerinde çocuklara daha çok uygulama ve yaşantı edindirilmeli."*

The participants were also asked whether they could suggest a real-life *problem status* in conjunction with the subjects that they found compatible with the educational robotics. Their suggestions were:

- Environmental problems
- Environmental pollution
- Problems in animal shelters
- Problems of people with disabilities
- Energy conservation
- Generation of energy
- Power distribution
- Help for baby-care

For the *presentation of problem scenarios,* participants suggested several ways such as making a video on the scenario, asking students their own problem status, encouraging students to dream problem status, and use of inquiry methods.

The low motivation level of students was one of the threats of the activities according to results of analysis of the current status in the implementation school. Therefore, a question was asked to the participants addressing this problem. One of the participants suggested starting a project which was suitable for the students' interests at the beginning of implementation. According to another participant, awareness should have been created first, and the intervention should have been endeared with some methods such as gamification. The introduction of competition organizations for the activities to the students, exhibition of the products and small rewards could be the ways to overcome this threat for the other participants. The other ways suggested were to let all the students have the feeling of success, according to the last participant.

The state of the readiness of students in science subjects was another possible problem that could be faced during the intervention. One participant stated that there would not be any problem about readiness since the students already studied these subjects recently in the 5^{th} grade. However, the related subject should have been waited in Science Course before the impelemtation of activities, according to another participant. A test could be utilized in order to decide the state of the readiness on the subject. The problem statement of the activities could be given as homework assignments to the students which require them to make an inquiry before the course hours, according to the last participant.

As one of the results of analysis of the current status, the activities should be appropriate for the students' cognitive levels. The participants suggested the followings to make activities into the *appropriate cognitive level* for the students:

- To explain the topic again and again
- To use clear and short sentences

- To expect to type the instructions by students or give these instructions in a printed format
- To make abstract concepts into a concrete format
- To give activities with video supported instruction
- To spend more time
- To care for students individually
- To increase the count of the games during the activities

To reduce the *extra workload* of activities, they can be organized as group works according to one of the participants. A mentor-student can be assigned to the groups, and peer learning can be provided. The next participant claimed that the instructor should work hard and prepare him/herself very well before the course hours. However, the last one thought that there would not be any extra workload.

According to another current status analysis result, the *course duration* could not be enough for the activities. The participants suggested to assign the students homework and arrange extra working hours after school time such as studios or training times.

In conclusion, the appropriateness of the grade level of the students is crucial for the activities since some administrative problems can be encountered during the process, especially at the eighth-grade level in middle schools. The choice of the subject should be based on the equipment of the robot kits. According to results, the types of equipment on the robot kits are proper for physic subjects, specifically for the subjects as heat and temp, light, sound, and friction force. Therefore, these subjects may be covered in the activities. Additionally, socio-scientific topics such as environmental education, savings, and renewable energy were suggested for the activities by the practitioners. The teachers also indicated environmental problems such as pollution and problems in animal shelters, issues about the people with disabilities and baby-care, energy conservation and generation, and distribution of energy as real-life problems in conjunction with the subjects. The inquiry method can be used for the presentation of these problem scenarios. Students can imagine the situation in this way, or a video can be used at the beginning of the activities.

A test on the selected subjects can be utilized to assess the readiness of students before the activities. Since the students have found the robotic tools very interesting, their interest can be utilized during the activities for motivation. However, the number of the robot kits should be taken into consideration to give students an equal chance to use the materials. During the activities, some technical problems can be encountered, but a technically equipped teacher may be enough to overcome these problems. To decrease the extra workload of activities, they should be implemented as group works. A mentor student in these activities can guide group mates, which will reduce the extra workload of the teacher who should work hard during the activities and prepare him/herself very well before the activities.

Additionally, explanations should be clear enough during the activities. The video supported or game supported instruction can be utilized to make abstract subjects concrete. There may be a need of dealing with students individually to make the activities into the appropriate cognitive level of students. The extra working hours should be given for the students since they need extra time apart from the course hours.

4.1.2.2 Preparation of Activity Sheets

The researcher developed the activity sheet, aiming to promote students to follow a problem-solving process during the activities. The development started with the literature review mainly on the problem-solving. Accordingly, this activity sheet contained sections that represented both the general problem and solving processes of ill-structured problems.

To give more details, this activity sheet presented a problem statement at the top of it. A problem scenario that represented a real-life ill-structured problem would be in this part of the sheet. The first and second sections of it contained trigger questions that were related to the student's understanding of the problem statement. Learners could articulate their problem space and contextual constraints here, and they could need to take some notes about the problem near to the trigger questions. The third section of the sheet contained a fishbone. In this part, the main reason and sub reasons were asked to the students. Students could identify alternative perspectives of the problem statement with the help of this section, and they might construct multiple problem spaces. The next section asked the students about possible problem solutions. They needed to type their solutions in this section and assessed their solution alternatives. In the fifth, sixth, and seventh sections, the requirements to implement the solutions were asked. Notably, the general requirements were asked in the fifth section, and required sensors and activators on the robotic kit were asked in sixth and seventh parts. By selecting these, students would have the chance to monitor their problem spaces by reflecting on what they knew about it. In the implementation part, they needed to draw the flowchart of the programming. The last section of the sheet asked the students' predictions about the solution. They had the chance to monitor their solutions by predicting the results. A note about going on the programming robots on the computers was presented at the end of the sheet.

Two experts in the field examined the sheet and made a number of changes on it. In addition, a new section for the selected solution was revealed as a need during the implementation process, and this section was added between the fourth and fifth sections. The final version of it is presented in Appendix K.

4.1.2.3 Preparation of Activity Scenarios

The first version of problem scenarios was developed in a focus group meeting including the researcher himself as well as an expert in science and teachers who were working at the middle school level. The demographic information of the participants of this focus group meeting is given in Table 4.4. According to the demographic information gathered from the participants, one of the participants was a male science teacher and 35 years old with 11 years of professional experience. In addition, an expert from the field of science participated in the meeting who was female and 29 years old with seven years of professional experience in the field. The remaining participants were males. One of them was 31 years old and has been working as an IT teacher for eight years. The other one was the researcher himself who has been working as a research assistant in the field of IT for eight years.

Table 4.4 Demographic Information of the Participants in Draft Activity Preparation Meeting

Participants	Gender	Age	Field	Professional Experience/Year
A	Male	33	Instructional Technology	8
B	Male	31	Instructional Technology	8
C	Male	35	Science	11
D	Female	29	Science	7

The first aim of this meeting was to develop the activity scenarios based on the suggestions of the experts in the previous phase. These suggestions were presented during the meeting. Additionally, the activity sheet was also introduced to the focus group members. Seven draft activity scenarios were developed during this meeting including subjects in Science and IT Courses, objectives in both courses, activity name, proposed problem scenario, and required equipment. The researcher noted the details of scenarios on a form during the interview. While one of the filled forms was given in Appendix E, the features of the scenarios were presented below separately.

Activity-1

⇒ **Activity Name:** Lifeguard Robot

⇒ **Science Subject:** Physical Events

⇒ **Unit and Sub-Subject:** Propagation of Light, Incoming Beam, Reflected Beam, Surface Normal

⇒ **IT Subject:** Problem Solving, Programming

⇒ **Scenario:** People sunbathing on the beach are damaged and they get various diseases when the angle of arrival of the sun's rays gets steep. Is it possible to design a robot that can help people in this situation?

⇒ **Equipment:** Deck chair model, cardboard, doll, electric torch

Activity-2

⇒ **Activity Name:** Scavenger robot

⇒ **Science Subject:** Creatures and Life

⇒ **Unit and Sub-Subject:** Human and Environment, Environmental Pollution, Environmental Protection and Beautification, Human-Environment Interaction, Local and Global Environmental Problems

⇒ **IT Subject:** Problem Solving, Programming

⇒ **Scenario:** Trash cans emit too many germs to their environment, which discomforts us too much. How can robots help us with this problem?

⇒ **Equipment:** Cardboard, rubbish

Activity-3

⇒ **Activity Name:** Savior robot

⇒ **Science Subject:** Creatures and Life

⇒ **Unit and Sub-Subject:** Human and Environment, Disruptive Nature Events and Protection

⇒ **IT Subject:** Problem Solving, Programming

- ⇒ **Scenario:** We know that people with disabilities have difficulty in natural disasters. How do robots help people with disabilities in natural disasters?
- ⇒ **Equipment:** Cardboard, doll

<u>Activity-4</u>

- ⇒ **Activity Name:** Robot factory
- ⇒ **Science Subject:** Physical Events
- ⇒ **Unit and Sub-Subject:** Measurement of Force and Friction, Applications of Friction Force on Slippery and Rough Surfaces, Applications of Friction Force in Daily Life
- ⇒ **IT Subject:** Problem Solving, Programming
- ⇒ **Scenario:** It is imagined that the students work in the robot factory. What can we do to make robots move on slippery surfaces?
- ⇒ **Equipment:** Different floors, material for differentiation of wheels

<u>Activity-5</u>

- ⇒ **Activity Name:** Robots Cleaning Lakes
- ⇒ **Science Subject:** Creatures and Life
- ⇒ **Unit and Sub-Subject:** Human and Environment, Environmental Pollution, Environmental Protection and Beautification, Human-Environment Interaction, Local and Global Environmental Problems
- ⇒ **IT Subject:** Problem Solving, Programming
- ⇒ **Scenario:** What robots can do to clean distant lakes?
- ⇒ **Equipment:** Bucket, bowl, rubbish

Activity-6

⇒ **Activity Name:** Waste Separation Robot

⇒ **Science Subject:** Creatures and Life

⇒ **Unit and Sub-Subject:** Human and Environment, Environmental Pollution, Environmental Protection and Beautification, Human-Environment Interaction, Local and Global Environmental Problems

⇒ **IT Subject:** Problem Solving, Programming

⇒ **Scenario:** In schools, garbage is usually thrown into the boxes prepared to collect papers, which damages the previously disposed of wastes and makes the separation work difficult. How can these robots help us?

⇒ **Equipment:** Paper, cardboard, glue, handcrafted paper, rubbish

Activity-7

⇒ **Activity Name:** Robotic Solar Panels

⇒ **Science Subject:** Physical Events

⇒ **Unit and Sub-Subject:** Propagation of Light, Smooth Reflection, Incoming Beam, Reflected Beam, Surface Normal

⇒ **IT Subject:** Problem Solving, Programming

⇒ **Scenario:** The solar panels should be placed in the best area of the mountain points. What can robots do to get more energy from these panels?

⇒ **Equipment:** Solar panel, cardboard, flashlight

In a meeting, these seven activity scenarios were reviewed and upgraded by an expert in the field of IT. These upgrades were mainly on the statements of problem scenarios, and contained real-life problem narratives. The taken notes about the scenarios in this meeting were applied to the activity sheets by the researcher before the assessment of these scenarios.

4.1.2.4 Assessment of Activity Scenarios

The activity scenarios with related subject names and the objectives of the subjects were presented in a form to four field experts who were different from the developer group. The demographic information of these participants is presented in Table 4.5. They reviewed the scenarios with the help of an instrument called "Problem Scenario Evaluation Form" (please see Appendix F). This form was developed by the researcher and consisted of two sections that contain items about the general characteristics and structured level of the problem scenarios, respectively. The data were obtained via a five-point Likert-type scale in which the reviewers could set their preferences by giving numbers from 1 (totally disagree) to 5 (totally agree).

Table 4.5 Demographic Information of the Participants in Phase of Evaluation of Problem Scenarios Phase

Participants	**Gender**	**Age**	**Field**	**Professional Experience/Year**
A	Female	33	Science	12
B	Male	35	Instructional Technology	6
C	Male	36	Science	10
D	Male	32	Instructional Technology	8

According to data provided in Table 4.5, only one of the participants was a 33-years-old female and the most experienced participant with twelve years in the field of science (Participant A). The second most experienced participant was in the same field, and he was 36 years oldwith ten years of experience (Participant C). The remaining participants were both males whose ages were 35 (Participant B) and 32 years old (Participant D). They had six years and ten years of experience in the field of IT, respectively.

The results of the evaluation of activity scenarios for the first part of the evaluation form and the general characteristics of problem scenarios are presented in Table 4.6. The averages of the participants' responses to the five-point Likert type scale were demonstrated in this table as the item basis. The totals of the averages were also displayed for each activity.

Table 4.6 Results of Evaluation of Activity Scenarios for General Characteristics

		Average Points						
Arguments	**Activities:**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
Item 1: The problem scenario is presented in an understandable way. *"Problem senaryosu anlaşılır bir şekilde sunulmuştur."*		5.00	4.00	4.50	4.25	3.75	4.25	4.00
Item 2: The problem scenario is consistent with the subject. *"Problem senaryosu belirtilen konu ile uyumludur."*		4.25	4.25	4.50	4.00	4.00	4.00	4.50
Item 3: The problem scenario is consistent with the cognitive level of the student group. *"Problem senaryosu öğrenci grubunun bilişsel seviyesine uygundur."*		4.75	4.50	4.00	4.50	4.00	4.00	4.00
Item 4: The problem scenario is suitable for the specified learning outcomes. "Problem senaryosu belirtilen öğrenme çıktıları için uygundur."		4.25	4.75	4.00	4.00	4.00	4.00	4.50
	Total of Averages:	18.30	17.50	17.00	16.80	15.80	16.30	17.00

The results of total averages of whole items in the general characteristics show that the highest score belonged to Activity-1 (=18.30) whereas the Activity-5 (=15.80) had the lowest average scores. Activity-2's total score was 17.50, and the total scores of Activity-3 and Acivity-7 were equal (=17.00). Activity-4 had a total average score of 16.80 while Activity-6 had the second-lowest total average score (=16.30).

When the results were examined through item bases, Activity-1's scenario was found as presented in the most understandable way (=5.00), and the scenario of Activity-5 had the lowest score on the presentation method (=3.75). For the second item of the evaluation form which was about the consistency of the problem scenario with the subject in science and instructional technology, Activity-3 and Activity-7 had the highest score (=4.50) whereas Activity-4, 5 and 6 had the lowest score (=4.00). Activity-1 was found as the most consistent scenario with the cognitive level of students (=4.75) while Activity-3,5,6,7 had the lowest scores on this item (=4.00). According to item 4 of the evaluation form, the most suitable activity scenario for the specified learning outcomes was found as Activity-2 (=4.75), and the lowest scores on the item for the specified learning outcomes belonged to Activity-3,4,5,6 (=4.00).

The researcher analyzed the second part of the evaluation form to determine the structural level of activity scenarios. The results of this analysis are presented in Table 4.7. This part of the form consisted of two divisions: "nature of the structure of the problem" and "nature of task environment", respectively. The items of 5,6,7,8 and 9 were all related to the nature of the structure of the problem while the remaining items were about the nature of the task environment.

Table 4.7 Results of Evaluation of Activity Scenarios Structure Level

		Average Points						
	Arguments **Activities:**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
Nature of the Structure	**According to the problem scenario…**							
	Item 5: the problem status is presented superficially. *"problem durumu yüzeysel olarak sunulmuştur."*	3.50	3.75	4.00	4.00	4.00	4.00	4.50
	Item 6: the goal is presented superficially. *"problemde hedeflenen yüzeysel olarak sunulmuştur."*	3.50	4.00	4.00	4.25	3.50	3.50	4.50
	Item 7: in order to create the solution, the problem status and/or the targeted situation must be interpreted.	4.75	4.75	4.50	4.50	4.50	4.50	4.50

Table 4.7 (cont'd)

	"çözümü oluşturmak için problem durumu ve/veya hedeflenen durumun yorumlanması gerekmektedir"							
	Item 8: the number of transactions and processes that can be applied to solve the problem is not exactly certain. *"problemin çözümü için uygulanabilecek işlem ve süreçlerin sayısı tam olarak belli değildir."*	3.75	4.50	4.50	4.50	4.00	4.00	4.50
	Item 9: there is no exact conversion function (formula, operation, rule, etc.) that can be applied to solve the problem. *"problemin çözümü için uygulanabilecek kesin bir dönüştürme işlevi (Formül, işlem, kural vs) yoktur."*	3.50	4.00	3.75	3.00	4.50	4.00	4.50
Nature of Task Environment	**Item 10:** the problem status is presented in a realistic context. *"problem durumu gerçekçi bir bağlam içerisinde sunulmuştur."*	4.50	4.50	4.25	4.00	4.00	4.00	4.50
	Item 11: there is a need to use context to solve the problem. *"problemin çözümü için bağlamın kullanılmasına ihtiyaç vardır."*	4.50	4.25	4.00	4.00	4.00	4.50	4.00
	Item 12: issues of which data will be used and how they will be organized to solve the problem are not clear. *"problemin çözümü için hangi verilerin kullanılacağı ve bunların nasıl organize edileceği konuları net değildir."*	3.75	3.75	3.50	3.50	4.50	4.00	4.50
	Item 13: information from multiple fields is needed to solve the problem. **"***problemin çözülebilmesi için birden fazla alan bilgisine ihtiyaç vardır."*	4.25	4.25	4.50	4.00	4.00	4.50	4.00
	Item 14: There is no single solution to the problem. Various solutions can be used to solve the problem. *"problemin tek bir çözümü bulunmamaktadır. Problemi çözebilmek için çeşitli çözüm yolları kullanılabilir."*	4.75	4.25	4.50	4.50	4.00	3.75	4.00
	Item 15: In order to evaluate the solution of the problem, multiple criteria should be examined. *"problemin çözümünü değerlendirebilmek için birden çok ölçütün incelenmesine ihtiyaç vardır."*	4.75	4.25	4.50	4.50	4.00	4.50	4.50
	Total of Averages:	45.50	46.25	46.00	44.75	45	45.25	48.00

The total averages for all the items in this part were calculated. According to this analysis, the highest score for the total averages of belonged to Activity-7 (=48.00) whereas the lowest one belonged to the Activity-4 (=44.75). This result indicated the structure level of activities. Therefore, it was concluded that the most ill-structured activity was Activity-7 (=48.00) while the most structured one was Activity-4 (=44.75). The remaining activities were sprinkled between these activities. The structure level of each activity was illustrated in a continuum that represents the typology continuum of problem-solving (Jonassen, 2010, p.25) in Figure 4-1.

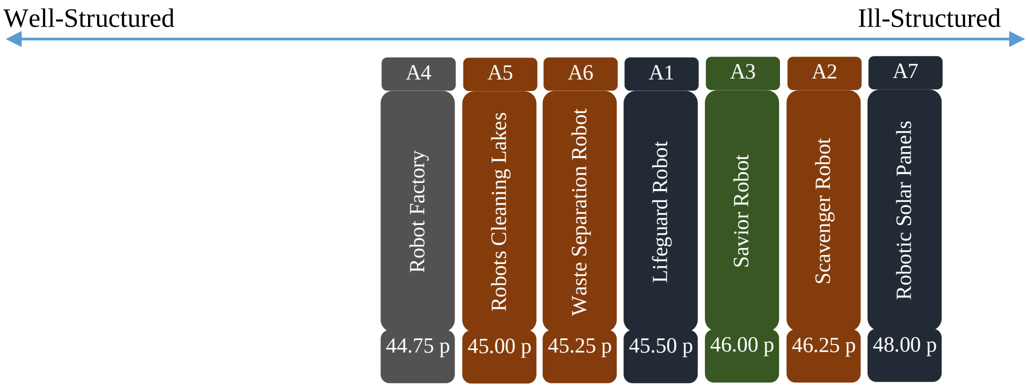

Figure 4-1 Structure Level Continuum of Activity Scenarios

When the results were examined through item bases, based on the responses of the experts to item 5 for the nature of the structure of the problem, the most superficial problem status belonged to Activity-7 (=4.50) while the least superficial problem status was on the Activity-1 (=3.50). In the same vein, responses to the item 6 indicated that the most superficial goal was presented in Activity-7 (=4.50) while the least superficial goal belonged to the Activity-1 (=3.50). According to the experts, in order to create the solution, the problem status and/or the targeted situation must have been interpreted (item 7) in all the activities. However, the mean of responses was more than others for Activity-1 and 2 (=4.75). For item 8, the most indefinite number of transactions and processes that could be applied to solve the problem was in the scenario of Activity-2,3,4, and 7 (=4.50) while the most certain number of transactions and processes were on the scenario of Activity-1 (=3.75). In item 9, the argument was that “there is no exact conversion function (formula, operation, rule, etc.) that can be applied to solve the problem”. According to the experts, the Activity-5 and 7 were the most compatible activities (=4.50) in line with that statement while Activity-1 was the least one (=3.50).

The remaining items of this part were all about the nature of the task environment. According to expert views, the problem status of Activity-1, 2, and 7 were presented in the most realistic context (=4.50) while in Activity-4,5, and 6 as the least realistic context (=4.00) based on the answers on item 10. The need for the context was asked in item 11. The mean of Activity-1 and 6 were the most (=4.50) and for Activity-3, 4, and 5 (=4.00) was the least. In item 12, the clarity of the issues regarding which data would be used and how they would be organized to solve the problem was examined. According to responses, the Activity-5 and 7 were the most unclear activities (=4.50) while the Activity-3 and 4 were the clearest ones (=3.50). The argument of “information from multiple fields is needed to solve the problem” was given item 13. The experts’ responses showed that they mostly reached an agreement on this statement for Activity-3 and 6 (=4.00) whereas it was the least for the Activity-4, 5, and 7 (=4.50). For the item 14, the participants of the analysis thought that the Activity-1 had the most various solutions (=4.75) while Activity-6 had the least (=3.75). For the evaluation of the solution to the problem, the majority of criteria were asked in item 15. According to responses, experts had the highest level of agreement on the statement for Activity-1(=4.75) while there was the lowest level of agreement for activity-5 (=4.00).

Since the number of activities is too much for the implementation, a selection between the activity scenario was foreseen so some of them were eliminated based on several criteria. Activity scenarios' comparison was made based on the criteria of related subject distribution, general score, and structure level score of activity scenario. Table 4.8 illustrated the information of activities based on these criteria.

Table 4.8 Activity Scenarios' Comparison

No	Activity Name	Subject	General Score	Structure Score
1	Lifeguard Robot	Propagation of Light	18.30	45.50
2	Scavenger Robot	Environmental Pollution	17.50	46.25
3	Savior Robot	Disruptive Nature Events	17.00	46.00
4	Robot Factory	Force and Friction	16.80	44.75
5	Robots Cleaning Lakes	Environmental Pollution	15.80	45.00
6	Waste Separation Robot	Environmental Pollution	16.30	45.25
7	Robotic Solar Panels	Propagation of Light	17.00	48.00

Since the Activity-1 (Lifeguard Robot) and Activity-7 (Robotic Solar Panels) were related to the same subject of propagation of light, the general score and the structure level scores of these activity scenarios were compared. The Activity-7 has a lower general score than the first activity. Its structure level score is also extremely different from other activities because its' interval score between the closest activity (Activity-2) is notably higher than the average interval score (0.54). Therefore, the Activity-7 (Robotic Solar Panels) was excluded from the study.

When the subject distribution was examined among the activity scenarios, the subject of Activity-2 (Scavenger Robot), Activity-5 (Robots Cleaning Lakes), and Activity-6 (Waste Separation Robot) were all related to the same subject as environmental pollution. The structure level score of these activities was used in elimination since Activity-5's and Activity-6's structure level scores were very close to each other as 45.00 and 45.25, respectively. Likewise, the structure level score of Activity-2 (46.25) did not exceed the interval score (0.54) between the closest score belonging to Activity-3 (46.00). Therefore, the general scores were compared between these activities. Since the general score of Activity-5 (15.80) and Activity-6(16.30) were the lowest general scores in the distribution and lower than the general score of Activity-2 (17.50), both activities were excluded from the implementation.

The sequence of the selected activities for the implementation was aligned, considering the structure level scores of the scenarios. Based on the data gathered from the Problem Scenario Evaluation Form, that the Activity-4 (Robot Factory) had the lowest structure level score (44.75) meant that it had the most structured problem scenario. In the second-order, the Activity-1 (Lifeguard Robot) was set, since its' scenario structure level score was 45.50. Activity-3 (Savior Robot) was the scenario whose structure level score was 46.00 and located in the third-order. The last activity was set as Activity-2 (Scavenger Robot) in the implementation sequence. The order of selected activities in the implementation is presented in Figure 4-2. The consensus was also ensured with an expert in the field and the teacher of the course on the decision of both the choice and the sequence of the activities for the confirmation.

Figure 4-2 Sequence of Selected Activities for the Implementation

4.2 Observation Before Activities

Before the implementation of the activities, the researcher observed the target group in the classroom environment to gather information about the characteristics of the target group and learning environment. Another aim of this observation was to get familiar with students since both the implementation itself and the researcher were novel for the target group and the teacher. Therefore, the observation was conducted at the schools before the first and the second cycles of the study. The researcher typed the data gathered from the observations at just in time of the observation itself. The data were transcribed after the observation and analyzed based on the three stages of the course, which was determined after the second week of the observation as beginning, activity, and closure parts. The duration of the observations was six weeks for the first cycle and four weeks for the second cycle of the study.

Based on the first cycle observation, for the beginning part of the courses, it was observed that students took their responsibility. Most of them did their homework and research before they came to the lessons. Lessons usually started with reminders of previous subjects and continued with informing of the objectives. The relationship between the previous subjects and the recent objectives was also established via the use of the question and answer method. The teacher was willing to use real-life examples to get students' attention to the subject, and the students usually reacted to these examples positively.

In the activity part of the lesson, it was observed that students knew the general problem-solving stages. When the teacher asked them, they could easily imagine the problem situation. They could argue several alternatives and creative solutions to the problem while they were using the fishbone technique. In several parts of the activities, the teacher preferred to use brainstorming to trigger students' argumentation skills. The use of the resources in the classroom was high whereas the utilization of group working was low. Students usually worked individually in activities but they were active in the activity process and willing to ask questions to the teacher.

In the closure part of the lesson, the summary of the subject was done with the students via the use of the question-answer method. If the activity was not finished until the bell rings, the homework would have been given to the students for following week. However, the bell was a critical stimulant since students did not usually wait for anything when it ringed once.

For the second cycle, it was observed that the previous subjects were reminded to the students at the beginning part of the lesson. The relations of subjects of robotics were constructed in this part of the lesson with the help of visual materials. Most of the students were willing to watch the subject related videos, and the robotic pieces were also getting their attention quickly. They were also feeling free to ask questions to the teacher.

In the activity part, the researcher observed that students were getting hard when they worked individually. However, they were familiar with working in groups, and they got help from their peers or the teacher when they faced a problem. The teacher usually presented a problem to the students, and they were capable of conducting the right processes to solve that problem. Similarly, the teacher usually utilized real-life examples and the question-answer method to teach the subject. In some parts of the lesson, the presentation method was also employed for the subject of the main usage and the alternative usage of the robotic pieces.

At the closure of the lesson, the subject was summarized. The students moved fast to empty the classroom when the bell rang since they needed to walk up to the other floor for the next lesson.

4.3 Modifications on Activities

After observing the learning environments of the implementation in both cycles, the activities began to take place with different schools. There were several changes on the activities during these cycles. These modifications began with the first activity and continued throughout the entire process. These modifications, based on the interviews with the participants, researcher's observations and video recordings, were applied in two different ways and identified as instant and long-term modifications. The instant modifications were mostly the changes during applications of the activities which should have been taken into the consideration for the following activities within the implementation of the cycles. These changes were immediate decisions during the application of the activities and applied with the consensus of the researcher with the teacher. In contrast, the long-term changes were the modifications of the activity that were applied in the same activity in the next cycle or the changes that concerned all of the activities. These modifications were based on the analysis of the first cycle data collected from interviews with participants and video recordings. Changes were applied to the related activity directy or the entire process of the second cycle after discussion with the teacher and getting approval from an expert in the field. All modifications in the process were represented in Figure 4-3 and summarized in Table 4.9.

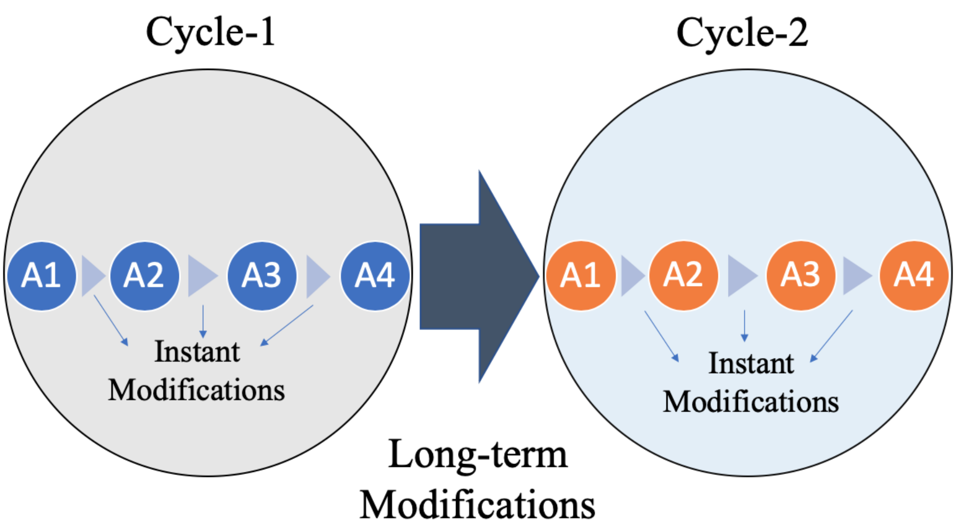

Figure 4-3 Representation of Modifications on Activities

According to data provided in Table 4.9, instant modifications of the activities were summarized on the basis of cycles of the implementation. In detail, instant changes in the auxiliary materials, the use of video, the distribution of stationery materials, teaching aids and group changes were required and applied during the first cycle of the implementation. Similarly, the need for an appropriate learning environment, adding another part to activity sheet, and giving homework to the students emerged during implementation of activities in the second cycle. In contrast to these instant modifications, a number of long-term modifications was considered between the cycles of the implementation. Among them, contextual modifications included the changes applied to the level of noise, competitive interactions between groups and duration of activities. The procedural modifications were the changes applied to the issues of the grouping method, the presentation of product, and the decrease in the participation of the activities. Some changes were also made on the evaluation problem in activities and pre-requirements of the activities, which were identified as instructional modifications. Similarly, resource-related modifications such as the change in activity sheet parts and stationery materials were also adopted like technical modifications on robotic pieces between cycles of the implementation.

Table 4.9 Summary of Modifications on Activities During the Implementation Process

Modification Type	Modification Source	Subject of Change
Instant Modifications	Cycle-1 Instant Modifications	• Auxiliary materials • Use of video • Distribution of stationery materials • Teaching Aids for sensors and activators • Group change
	Cycle-2 Instant Modifications	• Use of suitable learning environment • Additional part to activity sheet • Homework as an alternative road
Long-Term Modifications	Contextual Modifications	• Level of noise • Competition between groups • Duration of activity
	Procedural Modifications	• Grouping method • Presentation of product • Decrease in attendance
	Instructional Modifications	• Evaluation problem • Pre-requirements
	Resource-Related Modifications	• Activity sheet parts • Stationery materials
	Technical Modifications	• Robot pieces

4.3.1 Instant Modifications

Instant modifications of the activities were elaborated on the basis of cycles of the implementation process below.

4.3.1.1 Cycle-1 Instant Modifications

Auxiliary Materials: Before the activities, the teacher had preferred to give the students robot kits with all the parts attached to each other. In contrast, the students received these kits separately for the first time during the first activity. While the students were combining these parts there, it was seen that the wires of many parts of the robot were broken easily. This problem was verbalized by both the students and the teacher at the end of this early activity. Therefore, in order to fix broken wires, the second activity was started with a soldering machine as auxiliary material.

Use of video: Another instant change took place in relation to the utilization of the video case at the beginning of the activity. A teacher expressed a need for a video after the first activity in the first cycle. According to him, some of the students had problems in understanding the problem statement in the first activity. Therefore, video cases compatible with the problem scenario were created by the researcher in order to draw the attention of the students to the problem statement and make the problem situation clearer for them. Moreover, these videos were reviewed by the teacher before being presented to the students and included in the process after his approval in the remaining activities.

Distribution of Stationery Materials: The method of the delivery of stationery materials was changed several times throughout the implementation process. The first of them was in the form of the distribution to the students at the beginning of first activity. However, the time was wasted and at the same time the students' interests mostly shifted to these materials in this early form. In the second form, the students were able to access these materials at the beginning of the production phase of the activities. In this new form in the second activity, the order of priority caused another problem. Therefore, as a final form, the students could see these products at the beginning of the activities, but the process of obtaining them was determined according to the lot in the production stage.

Teaching Aids for Sensors and Activators: After the second activity of the first cycle, the teacher reported that the students did not remember the robot parts correctly and there were lots of questions about these parts, specifically about the sensors and activators. In order to reduce the workload of the teacher at this point, a reminder material that students could use was prepared and got ready on the smartboard. This material giving information about the shape of the sensors and the activators as well as the connection points on the robot was frequently used by the students during the remaining activities.

Group Change: Due to the approaching end of the semester, the number of students participating in the activity decreased significantly in the third activity during the first cycle. Students who previously attended activities with their own groups were informed that they could change their groups in this activity. Since the number of students decreased in the last activity, some groups had to be re-created in this activity.

4.3.1.2 Cycle-2 Instant Modifications

In the second cycle, a classroom change took place for some students in the classroom of male students. Although five students from another class were placed in groups as a replacement for the outgoing students in the second activity, disagreements were observed in groups in the next activity. Thus, group changes were made here as in the first cycle.

Use of Suitable Learning Environment: The laboratory where the activities were planned to be conducted contained two long tables in the second cycle. The students set in groups around these two tables there. However, they were not very appropriate for the group works especially for the groups of four members. A need for a suitable learning environment was observed by the researcher during the first activity, and it was also expressed by the teacher during the interview of this activity. Then, a meeting was arranged with the school administration to find a suitable classroom for the activities. After this meeting, the activity sheet was started to be filled in the school's library since it did not require any additional equipment. This learning place consisted of adjustable tables and chairs so that in this area, which was arranged according to the groups, the students could fill the activity papers with the contribution of all the group members comfortably. The laboratory was used in other parts of the activity because students needed the equipments such as computers in the programming and design phases of the activities.

Additional Part to Activity Sheet: The students were asked for their solution proposals to the ill-structured problems with a part on the activity sheet. However, they needed to choose one of them and created their flowcharts in conjunction with this selected proposal in the next part of the activity sheet. During the early activities in the second cycle, some students were observed that they had problems about focusing on the selected proposal. Furthermore, it was also observed that some of these students continued the activity by dividing the proposal section on the activity sheet into two sections and detailing their solutions there. Based on these observations, an additional part for students' solution proposal choice and further details about it was added on the activity sheet during the remaining activities in this cycle.

Homework as an Alternative Road: The last activity in the second cycle was scheduled for the last two weeks of the semester. However, an administrator came to the classroom during this activity and announced the immediate necessity of implementation of a pilot test that launched all over the country simultaneously. For this reason, the activity could not start at its exact time so the students were given an assignment to fill the first part of the activity sheet until the following week to complete the activity on time.

4.3.2 Long-Term Modifications

Several long-term modifications were carried out between the cycles of the implementation. These modifications were identified as contextual, procedural, instructional, technical and recourse related modifications. The details of these modifications were given below.

4.3.2.1 Contextual Modifications

Level of Noise: Since the context of the activities required intra-group and inter-group interactions, and the students were quite young, there was too much noise during the implementation of the activities in the first cycle. It was observed that the teacher and the students made various warnings to prevent the noise during the activities in all phases. One of the students expressed the difficulties due to the noise that they faced while filling the activity sheet in the first phase as follows:

> *A1_FG1_S2: For example, when you first gave the activity, some of our friends read twice because we did not understand anything due to the noise. So, I did not like this side of my friends.*
>
> *A1_FG1_S2: İlk verdiğinizde yaptığımızda mesela biz bazı mesela arkadaşımızın iki defa okuduğu zaman oldu çünkü gürültüden hiçbir şey anlamıyorduk. O yüzden arkadaşlarımızın bu yönünü beğenmemiştim.*

According to the results of the discussions with the expert and the teacher, unfortunately, there was not much to be done for this constantly ongoing noise situation apart from the increase of the targeted warnings. Thus, a rule was added to the activity prescriptions (please refer to Appendix N) prepared for the second cycle of the implementation. This rule, presented as the first rule of the activities, was as exactly as in the following:

“We must be quiet during group work. We should keep our voice at a level not to disturb our other classmates while talking in the group and with other groups.”

“Grup çalışması sırasında sessiz olmalıyız. Grup içinde ve diğer gruplarla konuşurken sesimizi diğer sınıf arkadaşlarımızı rahatsız etmeyecek düzeyde tutmalıyız.”

Competition between Groups: It was observed that they were in a race with other groups while they were working. In the activities separated into phases, this race was seen in the completion of that phase and continued with the desire to move to the next section before the others. The perception of this sense of competition resulted in demoralization in other groups, which was expressed by the teacher as follows:

A1_T: There were some students who thought that they could not do the task on time by looking at other groups. They told me that their friends had finished the task but they were left behind. Then, they said the others went to the coding part so they would not complete the task in time since they were still in the fishbone part.

A1_T: Şimdi şöyle öğrencilerin diğer gruplara bakarakyetiştiremeyeceklerini düşünen öğrenciler oldular, Bunu bana söylediler. Hocam biz geri kaldık, diğer arkadaşlar işte bitirdiler, kodlama kısmına geçtiler. Biz daha balık kılçığındayız şeklinde, hani yetiştirmeyeceklerini söylediler.

In addition to that, as a result of the sense of competition between the groups, the demoralization was expressed by a student as in the following:

A1_FG1_S1: Teacher, I was also tired of this: My friends came and told us that we could not make it, we did the same thing or ours was not appropriate. It happened so much.

A1_FG1_S1: Hocam ben bir de şunlardan yoruldum arkadaşlarım gelip bize sen yapamadın, sen aynısını yaptın, bu olmaz. Öyle çok oldu.

For this contextual problem, the teacher made the necessary warning to the affected groups as follows:

> *A1_T: I told them this was not a competition, there was no such thing as a reward at the end, and we did not choose the first or the second after all. - I said they did it right and were on the right track, and - they could bring it to the end of the lesson. I stated that being ahead of their friends would not create a negative situation for them becauseI received such a feedback from 1-2 groups in that group. In these groups, they already caught up with other friends and completed the activity like others.*

> *A1_T: Ben onlara bu bir yarışma değil, sonunda ödül gibi bir şey yok,birinciyi, ikinciyi falan seçmiyoruz. Sizlerde gayet iyi gidiyorsunuz, doğru yoldasınız, doğru yaptıklarını söyledim ve dersin süresi sonuna kadar da getirebileceklerini söyledim. Arkadaşlarının önde olmasının onlar açısından olumsuz bir durum oluşturmayacağını belirttim ki o grupta, 1-2 gruptan böyle bir dönüt aldım. Ogruplarda da zaten sonradan diğer arkadaşlarına yetiştiler, onlar gibi etkinliği tamamladılar.*

However, it has been discussed that a solution must be found for the groups causing it since the main source of the problem is not the affected groups. For this reason, an item was added to the activity prescriptions to prevent these behaviors that would adversely affect other groups during the activities.

Duration: The students were given four class hours for each activity in the first cycle. However, some of them complained about the insufficiency of the time given to finish. Especially in the production phase, it was observed that the students moved quickly to complete their product. The excerpt of S2 below implied the time-consuming aspect of this phase of the third activity.

> *A3_FG1_S2: There is a wall. We made a bed and a pillow. Half of the time was gone already while we were making the bed.*

A3_FG1_S2: Duvar var, bu var. Biz yatak yaptık, yastık yaptık. Zaten yatağı yaparken vaktin yarısı gitti.

Both the expert and the teacher agreed that additional time was needed for this phase of the activity. Therefore, the students in the second cycle were given six hours totally to complete the whole activity. While speaking of the duration of the activity, the teacher also brought to agenda that the students rushed into the creation of products without completing their programming of robots. In order to remove this situation, it was thought that the phases of activity should have been separated periodically within the total six hours. Accordingly, it was decided that the students would fill the activity sheet in the first two hours of the activities in the second cycle. Additionally, they would program the robots in the third and fourth hours. Then, it was planned that they would complete their design of products and present it in the last two hours. This schedule was also shared with the students in the activity prescription at the beginning of the implementation of the second cycle.

4.3.2.2 Procedural Modifications

Grouping Method: In the first cycle, the groups were formed by the students voluntarily at the beginning of the implementation. However, there were some problems about this type of grouping method. Several students did not want to be teared apart from the old groups formed in previous courses. One of thestudents was expressed this problem as such:

A1_FG1_S1: Teacher, I wanted because my friends, whom I have been in the same group in class before, did not let me join them so I was bored by this.

A1_FG1_S1: Hocam neden istedim çünkü benim bi arkadaşımlarım vardı daha önce derste birlikte olduğum da beni katmadılar ondan sonra benim canım sıkıldı.

This totally voluntary grouping method was changed in accordance with the recommendation of the field expert prior to the second cycle. This proposal was intended to ensure the heterogeneity of the activity groups. The expert claimed that groups formed in a systematic manner depending on the pre-requisites of the activities would eliminate several grouping problems, as in the case of failure to break up with friends. Several problems in groups during the activities would also be avoided in this way. Therefore, the groups should have been formed according to the results of the test on science achievement, unplugged algorithm quiz, or previous year grades on the related courses of activities as well as a social lesson such as Turkish. In line with this suggestion, groups were created heterogeneously at the beginning of the second cycle. The students in two different classrooms were divided into three groups depending on their previous year grades in Science, Information Technologies and Software (ITS), and Turkish Courses. Based on the background information, students' names were printed on the different colored cards. At the beginning of the first activity, the teacher distributed the students' cards by name. Based on the rule that groups had to contain all but different colors of cards, the students formed the heterogenous groups there.

Non-involvement into groups was another grouping problem during the first activity. The teacher reported that some students were excluded from the group work within the groups. He expressed this unfavorable situation as follows:

> *A1_T: I encountered minor problems during the group interaction such as some of our students got angry with their friends, thinking that they were not doing anything, they were not involved in the activity, or they were ignored by others. Therefore, this situation affected us negatively.*
>
> *A1_T: Bazı öğrencilerimizin grup etkileşimi sırasında, arkadaşlarıyla küsme durumlarının olması, hani Ben bir şey yapmıyorum gibi düşünmeleri, ya da sürece Beni almıyorlar, benim dediklerimi yapmıyorlar şeklinde ufak tefek bu gibi sorunlarla karşılaştım. Bu hani bizi olumsuz etkileyen bir durum oldu.*

To change this, a situation observed in the first cycle was presented to the students as a rule in the second cycle. In fact, it was observed that the students established the division of labor during group work in the first cycle. They expressed the underlying reason for this division as limited time of the activity during the focus group meeting. The determined labors were on the filling activity sheet, programming and the design issues, according to the data analysis. These labors were presented as responsibility to the students in activity rules at the beginning of the second cycle of the implementation. According to this rule, one of the students in groups were responsible for the activity sheet. This student, who was responsible for carrying and picking up the activity sheet, would also fill the activity sheet in line with the opinions of groupmates. The student, who was responsible for the computer, would develop the algorithm on the computer with the help of groupmates and transfer it to the robot. Material officer was the student who would participate in the lot for the selection order of the materials and be responsible for the use of these materials by taking the opinions of his group friends. Thus, it was ensured that all the group members took over some of the responsibilities on the work and tried to prevent the situation of exclusion from the group in the second cycle.

There was a lunch break between the course hours during the implementation of the activities in the first cycle. In several activities, this gap between the course hours caused a decrease in members of groups. Some students available in the morning session did not attend the classes in the afternoon. Therefore, the groups had to continue the production phase of the activity with the missing person. This situation was reported by the teacher as the in the following:

> *A3_T: If the lesson remains in the afternoon, it creates a problem. We had one or two students who did not able to attend in the afternoon so the student in a group remained single. While creating the product, he had to produce alone. Of course, the reason for it was that it was towards the end of the year and there was no necessity of attendance. So, students were more relaxed and they were able to take the initiative to avoid coming to school.*

A3_T: Ama öğleden sonraya dersin kalması şöyle bir sorun. Öğldene sonra gelemeyen yine bir iki öğrencimiz vardı hatta bir gruptaki öğrencimiz tek kaldı. Ürün oluştururken tek başına ürün oluşturmak durumunda kaldı. Tabi bu da işte yıl sonu olması, bundan dolayı devam devam sorunun olmaması, notlarının olmamasından dolayı öğrenciler biraz daha rahatlar ve okula gelmeme noktasında inisiyatif kullanıyorlar.

A rule was put in the activity prescription created for the second cycle in case a person was missing from the group. According to this rule, the task of the person who could not continue the activity would be taken over by other group members and the activity would continue in this way.

Presentation of Product: During the first cycle, the students presented the product to their teacher and to the researcher at the end of the activities. These presentations were performed in front of the board. The groups who solved the ill-structured problem and developed their product came to the presentation area and started to present their work as a group. This presentation was recorded by the researcher. It was interesting that although the other students were not particularly invited to these presentations, lots of them were eager to come and watch their friends' presentations. It was observed that only the groups which could not finish yet were not interested in these presentations. The teacher suggested that these presentations should be made for the whole classroom during the last activity of the first cycle. However, this change, which could not be made in that activity since the time period was not suitable for the presentations, was applied to the activities planned more flexibly in the second cycle. The suggestion of the teacher during the interview of the third activity for this change was as follows:

A3_T: The students designed their products. They programmed it firstly and then finally created the product and brought it to the presentation area. Something can be done at the point of presenting it to the whole class. If there is time left in the last activity, it may be better to tell the friends about *this topic, to explain the activity to the whole class and to show that product to the friends.*

A3_T: Çocuklar ürünlerini oluşturdular, tasarladılar. Programlamasını yaptılar ve daha sonra da en sonunda işte ürünü oluşturup onu sunum bölümüne getirdiler. Yani sunarken hani bir şey olarak aslında tüm sınıfa sunma noktasında bişey yapılabilir. Belki son etkinlikte zaman kalırsa yapılan etkinliği tüm sınıfa anlatma o ürünü de gösterme hani çocukların arkadaşlarına bu konuyu anlatması daha iyi daha etkili olabilir.

Decrease in Attendance: The number of participants, which was quite high when the activities began, started to decrease towards the last activities in the first cycle. The reason for this was related to the time of implementation by the teacher. To him, this decrease was especially normal for the school where the implementation conducted. In this school, the students usually used their rights to be absent especially at the end of the second term. The fact that the activities coincided with the month of Ramadan also increased this decline. This was an issue to be considered at the beginning of the second cycle. The researcher met with the school administration for this purpose. The administrator said that there was no such problem in the new school and it was unnecessary to take a precaution against it.

4.3.2.3 Instructional Modifications

Evaluation Problem: Since the activities were performed by the students as group works in both cycles, it was not possible to monitor the students who worked much in that group. In detail, it was unclear which group member had that solution decision, who were the active in the process, or whether the division of the labor done appropriately in the group. Therefore, the assessment of the students' progress in activities was not easy in this cycle. This situation was expressed by the teacher as the in the following:

A4_T: Who learned better? Whose idea was it or why did they accept the idea of those friends but did not accept the others? Why was that student dominant in that group? Why didn't they take the other's opinion? For example, I do not know exactly those points or I do not know which students answered the questions. Did they make a joint decision or did only one student constantly answer the questions? I couldn't observe that episode.

A4_T: Kim daha iyi öğrendi? O fikir kimin fikri ya da neden o arkadaşlarının fikrini kabul ettiler de diğerlerini kabul etmediler? O öğrenci o grupta neden baskın oldu? Neden diğerinin fikrini almadılar? Mesela o noktaları tam olarak bilmiyorum ya da hangi öğrencilerin sorulara cevap verdiğini bilmiyorum. Çünkü ortak bir karar aldılar mı ya da sadece bir öğrenci mi sürekli sorulara cevap verdi? O bölümü gözlemleyemedim.

The problem about the assessment of group members were tried to be surmounted in the second cycle with the help of an instrument. The peer evaluation form (please see in Appendix O) was developed by the researcher with the expert advice and included items about the behaviors of the group members about the group work. The students assessed other group members according to these phases and they secretly brought their answers to the next activity. Thus, the contribution of the students to the activity in the group was tried to be determined in the activities of the second cycle.

Pre-requirements: The analysis of the first cycle data indicated that the students needed some pre-requirements to complete the activities properly. Filling the fishbone part of the activity to investigate the reasons of the ill-structured problem was one of these pre-requirements. The students were given instructions to fill the fishbone before the activities with some problems during the course time. However, it was observed that there were forgotten points and misunderstandings about this topic. The teacher expressed the lack in this matter as follows:

A1_T: They said whether they would fill all of the reasons in fishbone. They found the reasons, but they couldn't understand exactly where to write, so they could not comprehend it well.

A1_T: Fishbone'daki nedenleri oradaki kısımların tamamını doldurup doldurmayacaklarını söylediler. Nedenleri buluyorlar ama nereye yazacaklarını tam olarak şey yapamadılar onu idrak edemediler.

In addition to what the teacher stated, one of the students reported that they had difficulties in filling this part of the activity sheet during the focus group meeting of the third activity.

A3_FG2_S2: The things we did not like: there was a bit of difficulties in the question of the fishbone, so we didn't like that a bit.

A3_FG2_S2: Hoşumuza gitmeyen yönleri, bir tek şu balık kılçığı sorusunda birazcık takılmalar oldu o yüzden orası biraz hoşumuza gitmedi.

The problem about the fishbone made it necessary to remind the subject at the beginning of the implementation of the second cycle. Therefore, the teacher showed a working example and reminded them of filling the fishbone at the very beginning of the activities in this cycle.

Another problem on the pre-requisites emerged after the second activity in the first cycle as the instance of forgetting the robot pieces. This problem was instantly solved after this activity with a reminder presentation on those pieces. However, this application running on smart board would not be available in the second cycle since there was no smartboard in laboratory. Therefore, a reminder paper was prepared for the students. This paper was distributed to students at the beginning of the implementation and a rule saying that this paper should be kept by the students during the activities was added to the activity prescriptions.

The lack of knowledge on different usage forms of the robotic pieces was another problem for the activities. In fact, the different usage forms of the robotic pieces such as wheels were one of the requirements for reaching solution suggestions in the activities since the activities contained the ill-structured problems. The teacher expressed students' deficiencies in this as in the following:

> *A2_T: For example, the students tried to make curtains: a product made by installing curtains on the motor, but since they see the motor connected to the wheel constantly, there were questions about how to connect it.*

> *A2_T: Mesela çocukların perde yapmaya motorun ucuna perde takmaya çalışıp hani o şekilde bir ürün oluşturacaklardı ama hani motoru sürekli tekerleğe bağlı gördükleri için hani o noktada hani nasıl bağlayacaz nasıl takacaz diye sorular geldi.*

The expert suggested to show the students a video that contained the different usage forms of the robot pieces during the course hours for the elimination of this deficiency. Therefore, to introduce the robots to the students, a video containing examples which showed the different uses of robot parts was demonstrated at the beginning of the course hours.

In addition to different usage forms of the robotic pieces, the students were not able to know the installation of the robots during the activities since they did encountered the robotic kit as a whole during the course hours. Particularly, the students who took this kit piece by piece during the first activity had various difficulties, so both the teacher and the researcher were asked various questions about the installation of the robots. The teacher explained this as follows:

> *A1_T: I used to give the educational robots in a united way. Here, all the parts of the robot were all scattered. I gave all of the pieces such as the wheels, the body and the sensors to the groups in a scattered way and I asked them to install the robot for their own solution from the very beginning. The students in some groups, we can actually say almost all the groups, had difficulties in particular parts such as the issues where to connet or how to connect them.*

A1_T: Eğitsel robotları daha öncesinde ben kendim parçaları birleşik bir şekilde veriyordum. Burada ise tamamıyla robotun tüm parçaları dağınık bir şekilde idi. Tekerleği gövdesi algılayıcıların hepsini gruplara dağınık bir şekilde verdim. Ve tamamıyla en baştan robotu kendi çözümüne yönelik tasarlamalarını istedim. Öğrencilerim de hani burada başlangıçta bazı gruplar aslında hemen hemen tüm gruplar da diyebiliriz yani nereye bağlayacak ve nasıl yapacaklarını tam olarak belli noktalarda zorlandı diyebilirim.

A video was found on the web page of the robot kit that explained the installation of the robot. This video was added to the agenda before the activities to provide the students with an idea on the subject and to reduce the questions about the subject for the second cycle of the implementation.

For the third activity of the first cycle, although the problem scenario of the activity did not direct the students to specific disability groups or natural disasters, it was observed that the majority of the students turned towards only some of them and produced a solution accordingly. This situation was expressed by the teacher as in the following:

A3_T: The students focused more on the subject of earthquake, the issue of earthquake in natural disasters in this activity. I did not ask the students the reason of it, but it might be the case that the earthquake is the most experienced natural disaster in our country, in our lives, and the students know this or the solution to the earthquake is easier for them.

A3_T: Yani çocuklar baktığınız zaman daha çok deprem konusunu doğal afetlerde deprem konusunu işlediler. Bunun sebebi olarak da hani çocuklara sormadım ama şöyle bir durum olabilir hani hayatımızda, ülkemizde en böyle fazla yaşanan deprem ya da böyle en fazla yaşanan doğal afetin deprem olması çocukların hani bunu biliyor olmaları ya da o olaya yönelik çözümün daha kolay olması belki onları yönlendirmiş olabilir.

As the excerpt above implied that the perception of the students was the reason behind the point of the students' focus in this activity in the first cycle. For the same activity in the second cycle, a brainstorming activity after the video was suggested to recall the other disaster forms. The students were also tried to be informed that they could work on the different disability groups in this preparation phase.

4.3.2.4 Resource Related Modifications

Activity Sheet Parts: In the first part of the activity sheets, the students were asked whether they understood the ill-structured problem. Some of them needed guidance on this part by the teacher because they did not know how much they should have written. The teacher expressed this as in the following:

> *A1_T: In activity sheet, the students asked how they would write the problem in their own sentences. They asked such questions: How many sentences will we use? Will it be long? Will it be short?.*
>
> *A1_T: Sheet'te problem kendi cümleleriyle yazma kısmında nasıl yapacaklarını sordular. Oradaki kendi ifadeleriyle yazma kısmında hani kaç cümle yazacağız hocam? Uzun mu olacak? Kısa mı olacak? Gibi sorular sordular.*

To reduce the need for guidance in this part, the following description was added to the relevant space on the activity sheet.

> *"Do not forget! The number of sentences you will write for this and other questions is not important. You should try to write as clearly and understandably as possible."*
>
> *"Unutmayın! Bu soruda ve diğer sorularda yazacağınız cümle sayısı önemli değil. Olabildiğince açık ve anlaşılır bir şekilde yazmaya çalışmalısınız."*

In the part of drawing the flowchart, the students rarely drew algorithms different from one that could be loaded into the robot. As a result, there were differences between the algorithm they drew and the product. This specific case was put forward by the teacher is as follows:

> *A1_T: There is a situation like this, for example: they write the algorithm but a different product can emerge after he produces the algorithm. So that's the material at hand, or they writes the algorithm differently so the product can be produced different. At this point, there were some suggestions for solution when the products and algorithms do not fit. I think that point is a bit improvable.*

> *A1_T: Şöyle bir durum oluyor mesela algoritmayı yazıyor ama o algoritmayı robotuna, ürün ortaya çıkarırken hani farklı bir ürün ortaya çıkabiliyor. Yani eldeki malzeme o. Ya da algoritmayı farklı yazıyo, ürün farklı çıkabiliyo. Bu noktada hani ürün ve algoritmaların uymadığı bazı hani durumlar, bazı çözüm önerileri geldi. Hani orada, o noktanın biraz düzeltilebilir olduğunu düşünüyorum.*

The underlying reason for this was considered as the students did not take into account the robot parts or stationery materials in their hands while doing this part. It was also the same for the part where they created the solution proposals. So for these two sections, a warning notice was added to the activity sheets. The text, which included the warning that they should have considered the materials they had, is in the following.

> *"Taking into account the robot parts and stationery materials you have…"*

> *"Elinizdeki robot parçaları ve yardımcı malzemeleri dikkate alarak…"*

Stationery Materials: Insufficiency of the stationery materials restricted the students on production of the new solutions for ill-structured problems. This created a rivalry among the students in terms of taking these stationery materials. As a result of this observation in the first cycle, adequate amont of stationery materials were prepared before the activities by paying attention to the group numbers in the second cycle. Moreover, various problems related to the use of these stationery materials were also raised among the students. Some of them depended on the materials and these showed the researcher that the materials had to be checked before the activities. This change applied during the second cycle. Another problem with stationery materials in the first cycle was that some of the students expressed difficulties in using some of the stationery materials; for instance, they could not cut the cardboard properly. One of the students expressed this problem as follows. This problem indicated the need for guidance on these issues in the second cycle.

> *A3_FG1_S1: There were cardboards like this so we did not cut them with the scissors at all, you know.*
>
> *A3_FG1_S1: Zaten makasla çok da kesilmiyordu bile şu gibi kartonlarda vardı biliyorsunuz siz.*

4.3.2.5 Technical Modifications

Robot Pieces: Some of the students reported the problems about the robotic pieces during the interviews. The technical problem about transferring the programmed file from the computer to the robot was one of them. One of the student interviewed expressed this problem as in the following:

> *A2_FG1_S1: I guess there was something wrong with the computer or cable. This cable was not loading. It was said that the device was loaded successfully but it was not working in our robot.*
>
> *A2_FG1_S1: Bilgisayarda bir hata vardı herhalde veya kabloda. Bu kablo yüklemiyordu. Cihaza başarılı yüklendi diyordu ama robotumuzda çalışmıyordu.*

The reason behind this transferring problem was found to be related to the USB cable that used for the transfer of the file. Therefore, extra working USB cables were bought and made ready before the second cycle.

The teacher reported the damaged robotic pieces during the interview of the first activity. He said that he had to check them before the activity but he missed it. This discourse was also used to solve the problem. During the second cycle of the implementation, the robot parts were controlled by the teacher and the researcher before the activities. The teacher disclosed the following statement about the problem and the solution of it.

> *A1_T: I had to check if these materials were working before the activity. I saw some of the sensors were not working. I noticed that the normally working sensors did not work.*
>
> *A1_T: Daha öncesinde bu malzemelerin çalışıp çalışmadığını kontrol etmem gerekiyordu. Bazı algılayıcıların çalışmadığını gördüm. Normalde çalışıyor diye bildiğim algılayıcıların, çalışmadığını.*

The robot pieces were also got broken during the activities in the first cycle. Since it took time to repair these pieces, it often caused disruption in the implementation of the activities. This situation, especially related to wheels of the robots, was depicted by one of the student group as follows during the focus group interview:

> *A1_FG1_S2: We had a problem during the activity. We were doing it properly but the cable broke down suddenly.*
>
> *A1_FG1_S3: We got annoyed. We were reassembling, it came away. We were reassembling, it came away again. It was very beautiful after you did it, but it came away again.*
>
> *A1_FG1_S2: That is why the cable made us a little bit nervous today. Also, the wheels didn't come out. One of the wheels was installed incorrectly. He also made us nervous.*
>
> *A1_FG1_S2: Şimdi bizim şöyle bir sorunumuz ortaya çıktı. Biz şimdi yapıyoruz birden kablo koptu.*

A1_FG1_S3: Gıcık olduk. Takıyorduk çıktı, takıyorduk çıktı. Ondan sonra çok güzel oldu. Siz yaptınız sonra tam takıyorduk yine çıktı.

A1_FG1_S2: Yani o yüzden kablo bugün bizi biraz sinirlendirdi. Ayrıca tekerlekleri çıkmadı. Tekerleklerin biri yanlış takılmış o çıkmadı. O da bizim sinirimi bozdu.

To overcome the problem with the robotic pieces, it was offered as a solution that there should have been extra robot kits during the activities. Therefore, the second cycle of the implementation was started and continued with five extra robot kits.

Insufficiency of robot pieces was another issue that restricted the students during the activity time. However, since the robot kits were taken ready from a robotic company and it was not possible to add new pieces to these kits, the modification on the activities for the solution of this issue was not found as applicable directly as a result of the discussion with the teacher and the expert. However, it was concluded that it would be appropriate to warn students that they should have proceeded in the activities by considering the robot pieces at the beginning of the implementation of the second cycle.

4.4 Enablers and challenges of problem-solving activities designed for middle school students to solve ill-structured problems in science with Educational Robots (RQ1)

The first sub-question of the study aimed to reveal the enablers and challenges of the activities in which students solved ill-structured science problems by using Educational Robotics. Since the question was twofold, its' results were presented into two sections below. These sections were named "Enablers of Problem-Solving Activities" and "Challenges of Problem-Solving Activities", respectively.

Enablers of Problem-Solving Activities

Learning and Instructional Enablers

The findings of the current study indicated that there were two themes for the enablers of the activities called learning and instructional enablers and facilities. *Learning and instructional enablers* theme was constituted entirely by the categories about the educational aspect of the activities. This theme was explicitly categorized as *motivation, guidance, high level of readiness, working with the group, solution strategies, effective communication,* and the *essence of the activity.* These categories were presented in Figure 4-4.

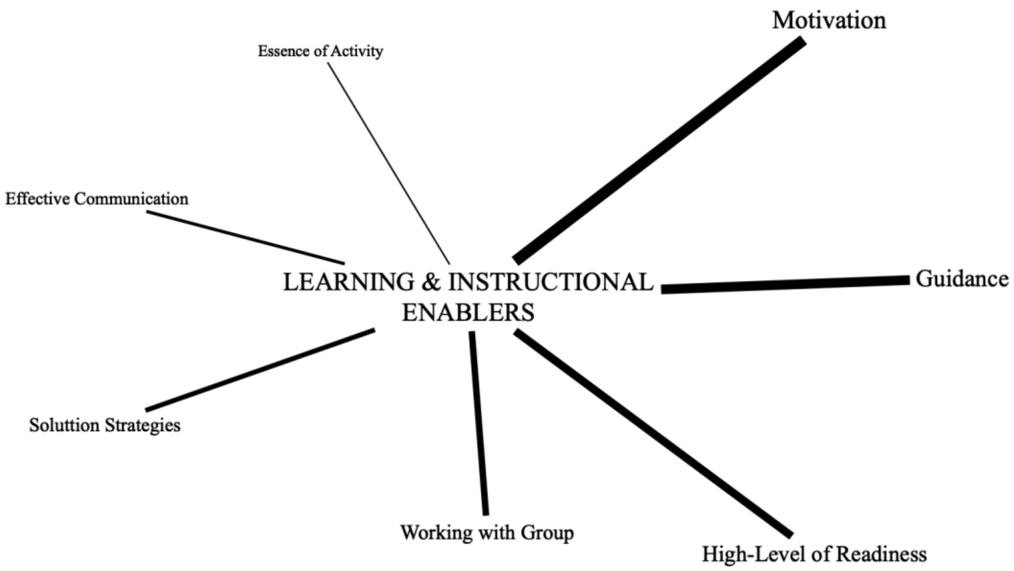

Figure 4-4 Categories of Learning and Instructional Enablers Theme

These categories emerged out of the main data source gathered from the interviews with the participants. In fact, the researcher interviewed the teacher and the students as focus groups separately after each activity in both cycles. However, the number of students in focus groups varied depending on the activities throughout the implementation process. In detail, only four students participated in the focus group meeting conducted after the first activity in the first cycle of the implementation. The number of interviewed students increased to five and six in the second and third activities, respectively. At the end of the implementation in this cycle, only three students were interviewed during the focus group meeting after the last activity. In the second cycle, the number of interviewed students were quite high in comparison to the first cycle since there were two different classrooms, which separated according to the gender of the students. In detail, the total number of interviewed students was 10 in the first activity in this cycle. Then, 11 and 15 students volunteered to participate in the focus group meetings after the second and the third activities. At the end of the implementation of all activities, the focus group meeting was conducted with eight students in this cycle. Based on the data gathered from these students and the teacher, a code tree in which the categories of the theme with the related codes listed from the most cited to the least was presented in Table 4.10. Each category and the related codes of the learning and instructional enablers of the activities were elaborated one by one after this illustration.

Table 4.10 The Code Tree of Learning and Instructional Enablers Theme

Categories/Codes	Σf
Motivation	**130**
Entertainment	63
Facilitative Resources	29
Satisfaction	20
Engagement	18
Guidance	**108**
Teacher	74
Researcher	30
Peer	4
High Level of Readiness	**98**
Pre-requisites	80
Previous Instruction	18
Working with Group	**49**
Cooperation	35
Forming Groups	14
Solution Strategies	**41**
Trail & Error	15

Table 4.10 (cont'd)

	Imagination	10
	Consensus	9
	Collaboration	7
Effective Communication		**34**
	In-Activity	30
	Out-of-Activity	4
Essence of Activity		**32**
	Activity Time	21
	Problem Scenario	11

Motivation

It was observed that the motivation of the students was quite high during the activities in both cycles. According to the data analysis, this motivation level was one of the learning and instructional enablers of the ill-structured problem-solving activities. The underlying factors of this enabler were specifically derived from the codes of entertainment, facilitative resources, satisfaction, and engagement. The frequency distribution of these codes was presented below (Table 4.11) regarding the activity numbers and the participants.

Table 4.11 Frequency Distribution of Codes belongs to Category of Motivation

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Entertainment	1	17 (*n*=4)	-	3 (*n*=3)	5	14 (*n*=6)	-	1 (*n*=1)
	Facilitative resources	8	-	4	2 (*n*=1)	7	1 (*n*=1)	-	-
	Satisfaction	2	-	-	3 (*n*=2)	2	3 (*n*=2)	-	-
	Engagement	4	1 (*n*=1)	1	-	-	-	-	4 (*n*=2)
Cycle 2	Entertainment	-	9 (*n*=7)	-	6 (*n*=4)	-	6 (*n*=4)	-	1 (*n*=1)
	Facilitative resources	-	2 (*n*=2)	-	3 (*n*=2)	-	-	2	
	Satisfaction	-	1 (*n*=1)	-	4 (*n*=3)	-	4 (*n*=3)	-	1 (*n*=1)
	Engagement	4	2 (*n*=2)	-	-	-	-	2	-

*n *refers to the number of students responsible for the verbal occurrences within interviews*

Entertainment

The findings presented in Table 4.11 revealed that entertainment during the activities motivated the students throughout the problem-solving process. The results of the students concerning the frequency of this code were quite high at the first activities in comparison to the others in both cycles. In detail, all the interviewed students (*n*=4) reported this source of motivation during the focus group meeting of the first activity (*f*=17) in the first cycle. In another group meeting, three students described the entertainment during the activities motivated themselves after the second week of implementation (*f*=3). Next week, six interviewed students mentioned this motivator quite more (*f*=14) as seven students described entertainment as a motivator for Activity-1 (*f*=9) in the second cycle. In this cycle, four interviewed students reported six times the entertainment with similar expressions for the second and the third activities (*f*=6). On the other hand, only one of the interviewed students mentioned it during the interview of Activity-4 (*f*=1) with a lower frequency than other activities in both cycles.

In descriptions, the students mostly reflected that the first phase of the activity, specifically paper works in it, was very entertaining. For some others, the remaining phases of the activities, the programming and the production phases were also entertaining in separate ways. In all these phases, the students worked in groups together, and several students emphasized that collaboration in group works made the problem-solving process entertaining. Additionally, some of the students described the overall activity had an entertaining aspect independently. One of these students expressed this in the reflection paper as follows:

> *C2_A4_R_S3: Teacher, first of all, all the four activities and studying with you were very very entertaining]*
>
> *C2_A4_R_S3: Öğretmenim öncelikle yaptığımız dört etkinlik ve sizle ders işlemek çok ama çok eğlenceliydi.*

S3's statement in the reflection paper implied the importance of the teacher's role in the development of the learning environment during the activities. The teacher, who tried to motivate the students by entertaining them during the activities, pointed out the motivational aspect of entertainment in the first activity for the first time (f=1) at the beginning of the implementation, and repeated it in the third activity (f=5) of the first cycle, according to the data provided in Table 4.11. However, he did not mention it in the interviews during the second and the fourth activities in this cycle, as well as all the activities in the second cycle.

The teacher expressed that the activities had several entertaining aspects as those mentioned above by the students. He commented that one of these entertainment sources of activities, the design, removed the boredom of some stages of the activities. Therefore, the students could work more efficiently. The teacher described this during the interview of the third activity in the first cycle as follows:

> *C1_A3_T: The existence of design makes students' work more entertaining. The students do not feel bored in several phases of programming robotics on the computer during the design phase. We can say that they feel less bored.*
>
> *C1_A3_T: Tasarımın olması çocuklardaki işi daha eğlenceli hale getiriyo. Robotik programlamanın o bilgisayardaki o proramlamanın bazı noktalardaki o sıkıcılığını tasarım bölümüyle çocuklarımız hissetmiyorlar. Daha az hissediyorlar diyebiliriz.*

Facilitative Resources

According to the findings, resources of the activities provided students during the activities motivated them during the problem-solving process. These resources were the enabling factors of the activities and labeled as facilitative resources, specifically. The utilized visual materials in activities were some of these resources. In fact, the students usually watched an introduction video, which contained the presentation of the problem statement at the beginning of activities. However, this introduction video was not applied to all activities. For instance, in the first activity of the first cycle, the need for a video was not clear yet, and the modification for introduction with a video was not applied to activities. Similarly, it was not utilized in the fourth activity of the second cycle since the activity sheet was assigned to the students as homework. Therefore, the students in this activity did not watch an introduction video, too.

When an introduction video was utilized, the researcher developed that video in conjunction with the activity's problem statement, and the teacher checked it before the corresponding activity. According to the findings, this specially prepared video motivated the students during the activities as well as another visual, the slide show, was developed to remind the students of the robotic pieces on the smartboard when needed.

In addition to visual materials, the equipments of activities such as computers, robots, and stationery materials were the other facilitative resources. The students mentioned all these facilitative resources as motivators, not as much as the teacher during the interviews, according to the data in Table 4.11. In fact, only one of the interviewed students expressed these resources during the focus group meeting of Activity-2 (*f*=2) and Activity-3 (*f*=1) in the first cycle. Additionally, only two students during the first (*f*=2) and second (*f*=3) activity meeting reported that these resources motivated them during the problem-solving process. Among these interviews, one of the students expressed the use of the computer as a motivating element by expressing the following statements:

> *C1_A3_FG1_S2: We liked it since we did it on the computer. It is a little more entertaining to do it on the computer because in other courses you should open your notebook, you do it there and it is hard. You do it here immediately so it's entertaining.*

> *C1_A3_FG1_S2: Bilgisayarda yaptığımız için hoşumuza gitti bir de. Bilgisayarda yapmak biraz daha eğlenceli çünkü diğer derslerde defterini*

açıyorsun, yapıyorsun falan zor oluyo. Bunda hemen yapıyorsun eğlenceli oluyo.

Like the computers in the excerpt above, the facilitative resources were reported by the teacher mostly in the first cycle. To give more detail, he reported these resources as a motivator 19 times during the first cycle interviews, according to the data in Table 4.11. He commented on these resources during the interview of Activity-1(*f*=8) and Activity-3 (*f*=7) more frequently than other activities. The remaining codes belonged to the interview of Activity-2 (*f*=4) in this cycle and Activity-4 (*f*=2) in the second cycle. He expressed the positive effect of the utilization of video for grabbing students' interest and attention during the interview of Activity-3 in the first cycle as follows:

C1_A3_T: The use of the video was more effective in attracting children's interest and attention. That was positive.

C1_A3_T: [Videoyu kullanmamız çocukların ilgisini ve dikkatini çekmesi noktasında daha etkiliydi. Olumlu oldu.

Satisfaction

The students utilized the facilitative resources while they were working in groups during the activity process. In fact, working with groups was not a novel instructional method for them. The observation before the activities in both cycles indicated that the students had already been working in groups during the course hours. The interview with them also showed that they had been incorporated into group works in other courses. Nevertheless, most of the interviewed students expressed that the number of group activities should have been increased substantially. They clearly explained that they were highly satisfied with working in groups during problem-solving activities.

In addition to working with groups, the solution for the problem, and the overall activity were other sources of satisfaction for the activities. The students usually had positive feelings at the end of the activities since they succeeded in solving the problem. Also, some students saw the activity process as a whole and all the work done in this process was described as satisfying. Two of the students' description picked among the data about these satisfactory resources were as follows:

> *C2_A1_D_S1: Then our robot became ready to serve customers. The robot has become a very successful and a proper robot thanks to its wheel and distance sensor.*
>
> *C2_A1_D_S1: Daha sonra da kullanacak hale geldi ve artık müşterilerin hizmetine hazır oldu robotumuz. Robot tekerlek ve mesafe algılayıcısı sayesinde çok başarılı ve düzgün bir robot haline geldi.*
>
> *C2_A2_R_S4: I liked everything in this activity, and I was satisfied with everything.*
>
> *C2_A2_R_S4: Bu etkinlikte her şey hoşuma gitti bütün her şey içime sindi.*

These sources of satisfaction were not mentioned by the students in an equal way for all the activities throughout the implementation process. For instance, they did not describe their mood as satisfied during the interviews of the first and fourth activities in the first cycle. However, the frequency of satisfaction was equal for Activity-2 and Activity-3 in this cycle. Two interviewed students expressed that they were satisfied with these activities (*f*=3). For the second cycle, the interviewed students called themselves as satisfied more while describing Activity-2 and Activity-3. In detail, for each of these activities, three interviewed students expressed their satisfaction with the activities (*f*=4). On the other hand, only one of the interviewed students reported this satisfaction during the interview of the fourth activity (*f*=1) and the first activity (*f*=1), according to the findings in Table 4.11.

Based on the findings provided in Table 4.11, the teacher mentioned students' satisfaction with activities for only the first cycle of the implementation. He described the students as satisfied in the process of Activity-1 (*f*=2) and Activity-3 (*f*=2) in this cycle. However, he did not report the satisfaction of students in Activity-2 and Activity-4 in this cycle.

According to the teacher, the students produced original products in these activities. These products induced the students to feel satisfied with their work because they had seen the results of the solution concretely there. This sense of satisfaction had a positive effect on the activity process. He expressed this as follows:

> *C1_A3_T: The fact that students saw concrete solutions that would work made them happy. This even entailed a positive impact.*

> *C1_A3_T: İşe yarayacak çözüm önerilerini somut bir şekilde görmüş olmaları onları mutlu etti ve daha da olumlu yönde bir etki sağladı.*

Additionally, a closure program was carried out at the end of all the activities. The teacher gave students a certificate of attendance at this event. There was a text of gratitude which contained each student's name on this certificate (please see in Appendix P). The teacher handed out the certificates to the students, and photos were taken at the end of this event (Figure 4-5). Students seemed extremely happy in this figure. The observation of the researcher also supported that students were satisfied with getting a certificate. Therefore, this certificate of recognition should be taken into consideration as a source of satisfaction. However, it was not mentioned during the interviews with participants. The reason behind this could be that these interviews were conducted before the closure event.

Figure 4-5 The Photo of Closure Program in Cycle-1

Engagement

Students' engagement in the activities was an additional finding for their motivation. According to participants, several properties of activities engaged students in the problem-solving process. For instance, the students were highly active during the activities. They intensively worked on the solution of the problem. As a result, most of them did not want to go outside at break time between the activity hours. Furthermore, they constantly asked the teacher and the researcher whether they continued to carry out similar activities.

According to the data displayed in Table 4.11, the engagement was reported mostly by the teacher in both cycles. The findings of the frequency of the teacher's descriptions concerning students' engagement for Activity-1 (f=4) in the first cycle, and the same activity in the second cycle (f=4) were quite high in comparison to other activities in both cycles. In contrast, he never mentioned the engagement of the students during the interviews of Activity-3 and Activity-4 in the first cycle as well as Activity-2 and Activity-3 in the second cycle. In one of the remaining activities, he described students' wish for doing further activities as such:

C1_A1_T: Teacher, let us study the course of Instructional Technology again. Teacher, will we do something similar to this event? Are we going to do another activity? Please let us do. I have received such positive feedback. This activity increased the motivation of the children towards the course.

C1_A1_T: Hani bilgisayar dersi hocam hani bir daha görelim, hocam bu etkinliğe benzer etkinlik yapacak mıyız, başka etkinlik yapacak mıyız hocam şeklinde. Yapalım hocam şeklinde olumlu dönütler aldım. Hani çocukların derse olan motivasyonunu arttırdı bu yaptığım etkinlik.

The findings demonstrated in Table 4.11 indicated that the students described their growing engagement in the activities during the Activity-4 and Activity-1 in the first cycle and Activity-1 in the second cycle. In detail, one of the interviewed students mentioned this engagement during the first activity the first time. Then, two different students expressed their engagement during the focus group of Activity-4 (f=4) in this cycle. In the second cycle, only two interviewed students reported this issue after the first activity (f=2). During these interviews, they reported that they were willing to perform similar activities as in the teacher's excerpt. Additionally, they expressed that they had a desire to do better during the activities, which was found as another source of engagement. One of the students expressed this desire during the interview of the last activity in the first cycle as in the following:

C1_A4_FG1_S1: Teacher, we need to prepare the robot better. If we do bad, it won't make sense.

C1_A4_FG1_S1: Hocam robotu da iyi hazırlamamız gerekiyo. Kötü yaparsak bi anlamı kalmayacak ki.

Guidance

The students engaged in activities needed some assistance during the activities since they had to tackle several challenges in all stages of the activities. For instance, they usually had problems with the parts of the activity sheet in the first stage. Similarly, they often faced challenges in their algorithms during the programming stage. In the last stage, they met problems with the design of the product. However, most of these problems were solved via guidance as the participants claimed. Therefore, it was labeled as one of the learning and instructional enablers based on the data analysis. This analysis clearly indicated the sources of the guidance as *the teacher*, *the researcher*, and *the peer*, as seen in Table 4.12.

Table 4.12 Frequency Distribution of Codes belongs to Category of Guidance

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Teacher	22	4 (*n*=1)	12	3 (*n*=3)	10	6 (*n*=3)	-	2 (*n*=1)
	Researcher	-	-	-	-	-	3 (*n*=3)	-	-
	Peer	-	-	-	-	-	-	-	1 (*n*=1)
Cycle 2	Teacher	3	3 (*n*=3)	1	2 (*n*=2)	1	2 (*n*=1)	3	-
	Researcher	-	4 (*n*=3)	-	6 (*n*=4)	-	8 (*n*=7)	-	9 (*n*=7)
	Peer	-	1 (*n*=1)	-	2 (*n*=2)	-	-	-	-

**n refers to the number of students responsible for the verbal occurrences within interviews*

As a source, the guidance of *the teacher* and *the researcher* were very similar to each other during the activities. In general, both sources instantly *helped the students*, *controlled their work*, and *directed the process* when a need existed during the problem-solving process. Therefore, it should be noted that the responsibility of guidance was undertaken by the researcher and the teacher equally. However, the guidance of the teacher was mentioned more than the researcher's guidance in both cycles by the participants. In detail, the teacher's guidance was reported totally by the participants (*f*=74) far more frequently than the researcher's guidance (*f*=30), according to the data provided in Table 4.12. The potential reasons of this finding were elaborated within the discussion part of the study.

Teacher's Guidance

Based on the data presented in Table 4.12, *the guidance of the teacher* was reported as an enabler by the teacher more than students in the first cycle. The frequency of his descriptions for his guidance during the interview of Activity-1 (*f*=22) was much more than other activities. In contrast, he mentioned it for Activity-4 (*f*=4) as quite lower than other activities in this cycle. In the second cycle, he reported the teacher guidance during the interviews of all activities as well as the first cycle, but the frequency of his descriptions for each one was quite lower than the activities in the first cycle. In detail, he described his guidance as an enabler of the activities during the interview of the first (*f*=3) and the last (*f*=3) activities more frequently than the remaining activities (including Activity-2 and Activity-3, *f*=1). In one of these interviews, he explained his guidance as a *reminder on the equipment* of the activity during the design stage of the activity. According to him, the students fixed their works with this reminder. His expression about this guidance was the following:

> *C2_A4_T: For instance, they tried to design things they could not do since the stationery materials did not allow. At that point, I reminded them that these were the materials at hand and they made a correction according to it again.*

> *C2_A4_T: Mesela malzemeler elvermediğinden dolayı yapamayacakları şeyleri tasarlamaya çalıştılar. O noktada onlara eldeki malzemelerin onlar olduğunu hatırlattım ona göre tekrardan bir düzeltme yaptılar.*

The students also expressed *the guidance of the teacher* in both cycles based on the findings in Table 4.12. These findings indicated that the frequency of students' descriptions on the guidance of the teacher was not close to each other during the interviews of the activity in the first cycle. To give more detail, at the beginning of the implementation, only one of the interviewed students expressed the guidance of the teacher as an enabler of this activity four times during the focus group meeting. In the next week’s activity, three students mentioned this kind of guidance (*f*=3) during the interview. Then, the other three students expressed that the guidance of the teacher eased the process of the problem-solving activity during the focus group meeting conducted after the third activity (*f*=6). For the last activity, one of the interviewed students explained the guidance of the teacher as an enabler (*f*=2) in this cycle.

In the second cycle, the guidance of the teacher was mentioned by three interviewed students for Activity-1 (*f*=3) firstly. Then, two and one interviewed students expressed this guidance as one of the enablers of the activity process during the focus group meeting placed after the second (*f*=2) and the third (*f*=2) activities. For one of those activities, the student who *got help* from the teacher to overcome the problem with programming expressed this guidance as in the following:

> *C2_A2_FG3_S1: We had difficulty in uploading to the robot and we got help from the teacher.*
>
> *C2_A2_FG3_S1: Robota yüklemekte zorlandık hocadan yardım aldık.*

Researcher's Guidance

In contrast to the teacher's guidance, it was only the students who reported *the guidance of the researcher* during the data collection process. In the first cycle of this process, only three interviewed students mentioned this guidance during the focus group meeting of Activity-3 (f=3). On the other hand, the students in the second cycle expressed the guidance source as the researcher for all activities in the second cycle. In detail, three students expressed this source during the interview of Activity-1 (*f*=4) firstly. Then, four students described the guidance of the researcher as an enabler of the activity six times after the second activity (*f*=6). For the next activity, seven interviewed students referred to the guidance of the researcher (*f*=8) during the focus group meeting. Similarly, the other seven interviewed students also reported that they had utilized the guidance of the researcher as an enabler during the data collection meeting conducted at the end of the activities (*f*=9). In one of those activities, one of the students described the *researcher help* on the programming stage of the activities as follows:

> *C2_A2_FG2_S2: There is also something that, for example, we put into the wrong place at the beginning we got help from you.*

C2_A2_FG2_S2: Bir de şey var hocam kodluyoruz hocam bir şeyi mesela girişte yanlış yere taktık başta onda sizden yardım aldık.

The distribution of the frequencies of the students concerning the researcher's guidance indicated a surprising finding that this kind of guidance was mostly reported by the interviewed students in the second cycle as it was demonstrated by the data provided in Table 4.12. The frequency of their descriptions was also gradually increased throughout the activities in this cycle. The potential reasons for this finding were elaborated on in the discussion part of the study.

Peer Guidance

It was observed during the activities that while the students were working in groups to solve the ill-structured problems, several students asked for *help from their group mates* as well as the teacher or the researcher. According to these students, this help occurred mainly as *the exchange of ideas about robots and design issues*. They reported that this support affected the whole activity positively since they could handle lots of little problems on those issues themselves via this guidance. Therefore, it was an essential instructional and educational enabler of the activities.

According to data provided in Table 4.12, the teacher never reported peer guidance in the interviews in both cycles. Only one of the students mentioned this support for Activity-4 (f=1) in the first cycle. In the second cycle, one of the interviewed students described peer guidance as an enabler during the focus group meeting of Activity-1 (*f*=1) the first time. Then, the other two students repeated similar descriptions on peer's guidance during the meeting conducted after the second activity (*f*=2). Additionally, one of the students reported that he had some difficulties during the third activity process. He then reflected that he was able to deal with those difficulties with his *friends' support*, addressing to the following remarks in his activity reflection paper:

C2_A3_R_S5: There were times that challenged me in this activity, one of which was to unite the Robot. Thanks to them, when I had a hard time at the activity, my teammates helped me.

C2_A3_R_S5: Bu etkinlikte beni zorlayan zamanalar oldu bunlardan biri ise Robotu birleştirmek oldu. Etkinlikte zorlandığımda sağ olsunlar takım arkadaşlarım yardım ettiler.

High Level of Readiness

In addition to the guidance in the activities, students' level of readiness was a very important element for the progress of activities. In fact, while its deficiency caused various problems, *the high level of readiness* made things easier during the problem-solving process of the activities. Therefore, it was classified as one of the instructional and educational enablers of the activities. According to the results of the data analysis, two main factors were affecting this high level of readiness. The first underlying factor was *the level of prerequisites* while the other was the effects of *the previous instruction.* The frequencies and the frequency distribution of these two factors were presented in Table 4.13.

Table 4.13 Frequency Distribution of Codes belongs to Category of High-Level of Readiness

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Pre-requisites	1	7 (*n*=3)	-	11 (*n*=4)	-	13 (*n*=5)	-	3 (*n*=2)
	Previous Instruction	10	-	2	-	1	-	1	-
Cycle 2	Pre-requisites	-	17 (*n*=9)	-	11 (*n*=4)	-	8 (*n*=7)	3	6 (*n*=3)
	Previous Instruction	-	-	-	-	-	-	4	-

**n refers to the number of students responsible for the verbal occurrences within interviews*

Pre-requisites

It was obvious from findings provided in Table 4.13 that the students reflected *adequacy of the prerequisites* as an enabler of the activity process for all activities.

The frequencies of their descriptions on prerequisites for Activity-3 (*f*=13) and Activity-2 (*f*=11) were slightly higher than other activities in the first cycle. In detail, three interviewed students referred to the importance of the prerequisites for the readiness of the activity process during the focus group meeting of the first activity (*f*=7) firstly. Then, the other four students described the prerequisites as an enabler in the next week (*f*=11). After the third activity, five interviewed students expressed them again with the highest frequency in this cycle (*f*=13). At the end of the implementation in this cycle, two interviewed students reported the prerequisites of the activities for the readiness of the activities, lastly (*f*=3). In the second cycle, nine interviewed students agreed on the importance of the prerequisites for the readiness of the activities and they reported these prerequisites during the focus group meeting of the first activity (*f*=17). In the next activity, four interviewed students alluded to the prerequisites as an enabling factor of the activity process (*f*=11). Then, the other seven students talked about these prerequisites during the focus group meeting placed after the third activity (*f*=8) and three students who interviewed after the last activity (*f*=6).

The students specifically reported the prerequisites on *science subjects* of *temperature* and *sun rays*, *force*, *natural disasters*, *environment*, and *pollution*. These subjects were directly compatible with activity subjects, and they promoted higher productivity during the activities. Besides these compatible subjects, others such as *electricity*, *sound*, and *distance* were expressed as additional prerequisite subjects of science. Moreover, *the knowledge of robot pieces* and *usage of them* were addressed to by the students as the prerequisites of the Information Technology and Software Course. They also outlined the *knowledge of programming* as the prerequisites of activities. In detail, *the knowledge of flowchart, algorithm,* and *the use of the editor* was the emphasized prerequisites of programming. Among these subjects, one of the students expressed the necessity of prerequisites on the subject of Science Course as in the following:

C1_A3_FG1_S1: We had to get information about how the occurrence of an earthquake in the science class. If we hadn't learned what the earthquake was like in science class, we wouldn't have done it.

C1_A3_FG1_S1: Depremin nasıl olduğuyla ilgili bilgi almamız gerekiyodu önce fen bilgisi dersinden. Fen bilgisi dersinde depremin nasıl bir şey olduğunu öğrenmeseydik biz bunu yapamazdık.

According to the data in Table 4.13, the teacher reported the need of the aforementioned prerequisites for only two activities in the cycles of the implementation. In fact, he expressed some of those prerequisites for the Activity-1 (*f*=1) in the first cycle and for Activity-4 (*f*=3) in the second cycle. He expressed the necessity of prerequisites for the readiness of activity during the interview of Activity-1 in the first cycle as follows:

C1_A1_T: The students already had prior knowledge of both science and computer courses. Since they had prior knowledge, they knew exactly what they would do.

C1_A1_T: Çocukların zaten bir ön bilgisi hem fen bilgisi hem de bilgisayar dersinde bir ön bilgileri vardı. Ön bilgileri olduğu için çocuklar hani tam yapacakları şeyleri biliyorlardı.

Previous Instruction

The previous instruction was also found as highly related to the readiness of the students for the activities. The findings in Table 4.13 revealed that only the teacher explained the previous instruction as an enabler for the readiness of students. He mentioned the previous instruction as a factor of readiness of students for Activity-1 (*f*=10) more frequently than other activities in the first cycle. He continued to report the support of the previous instruction for the readiness of the students in the remaining weeks of the implementation in this cycle (including Activity-2, *f*=2, Activity-3, *f*=1, Activity-4, *f*=1). In the second cycle, he expressed the previous instruction as one of the enablers of the process during only the interview of Activity-4 (*f*=4).

The results obtained from the interviews with the teacher supported that having the previous instruction in the course was very important for conducting the activities. Specifically, *the used strategies* in previous instruction such as problem solving, or collaboration and *the similarities* of the activity subjects with the subjects in previous instruction considerably eased the activity process. The teacher expressed the similarity of previous instruction with activities as an enabler by saying the following:

> *C1_A3_T: In other words, we had already done an activity about disabilities while explaining the subject of paint in our course…These made our job much easier.*

> *C1_A3_T: Yani engelli konusunu da hani daha önce zaten dersimde engellilere yönelik paint konusunu anlatırken bir etkinlik yapmıştık…Bunlar da işimizi oldukça kolaylaştırdı.*

Working with Groups

Students who were ready for activities after the preparatory instruction worked in groups during the activities based on the selected instructional design framework, Collaborative Problem Solving. Besides the framework, the teacher also expressed the practical rationale to employment of working with groups as a method in the activities as the following:

> *C1_A1_T: And the number of our robots was few so when students were exactly in groups of three, that is, when they were threes, the robots would be enough. Otherwise, we would give our student a robot with incomplete parts. Since we could not give a fully working robot, it might reduce his/her interest. At that point, there might be problems.*

> *C1_A1_T: Bir de hani robot larımızın sayısı azdı ve tam olarak üçerli gruplar şeklinde, yani üçerli olduklarında, tam yetecekti. Diğer türlü*

öğrencimize tam çalışır bir robot veremeyeceğimiz için eksik parçalı bir robot verecektik. O da ilgisini belki azaltabilecekti, herkesin ki tamam hani onunki eksik olacağı için. O noktada belki sorunlar çıkabilirdi.

Although this method was seen as a necessity by the teacher, in fact, the findings of the current study showed that it was one of the crucial enablers of activities. Working with groups enabled the activities in terms of two aspects identified as *cooperation* and *forming groups*. The frequency distribution of these aspects and the total frequencies of them were presented in Table 4.14.

Table 4.14 Frequency Distribution of Codes belongs to Category of Working with Groups

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Cooperation	4	3 (*n*=2)	1	1 (*n*=1)	1	6 (*n*=5)	-	1 (*n*=1)
	Forming Groups	2	2 (*n*=1)	-	1 (*n*=1)	1	-	-	-
Cycle 2	Cooperation	2	5 (*n*=3)	-	1 (*n*=1)	1	5 (*n*=4)	1	3 (*n*=3)
	Forming Groups	2	1 (*n*=1)	1	1 (*n*=1)	1	-	2	-

*n *refers to the number of students responsible for the verbal occurrences within interviews*

Cooperation

The data provided in Table 4.14 revealed that the students described one of the aspects of working with groups, *cooperation,* as one of the enablers of the activities for all the activities of the implementation. In detail, the majority of the interviewed students agreed on the enabler (*f*=3) at the earliest activity in the first cycle. Then, a student expressed the enabling side of cooperation for the activities during the interview of Activity-2 (*f*=1). The frequency of five interviewed students' descriptions on the same enabler was slightly higher for Activity-3 (*f*=6). Lastly, only one of the interviewed students expressed the cooperation in group working as an enabler during the focus group meeting conducted after the last activity (*f*=1) in this cycle. In the second cycle, the frequency distribution of the descriptions on this enabler was very similar to the first one. At the beginning of the implementation, three interviewed students expressed it firstly (*f*=5). Then, one of the students interviewed after the second activity repeated the close expressions on the same enabler (*f*=1). Four students agreed on the cooperation in group working that eased the activity process during the focus group meeting placed after Activity-3 (*f*=5) like the other three students interviewed at the end of the implementation (*f*=3).

Based on the expressions of students concerning *cooperation*, it was found that they *easily engaged with their groups* since they cooperated with others during the activities. This cooperation provided an *overwhelming superior to working alone*. They highlighted that they could help each other instantly, and the projects were completed in time as a result of this cooperation. One of the students commented on this cooperation as follows:

> *C2_A1_FG2_S2: I think it's good. It's better to do something with our friends than to do something on our own.*
>
> *C2_A1_FG2_S2: Bence güzel. Bir şeyi kendi başımıza yapmaktansa o işi arkadaşlarımızla yapmak daha güzel oluyo.*

The teacher also expressed *cooperation* in group works as an enabler in several activities. He mentioned it during the interviews of Activity-1 (*f*=4) more frequently than other activities in the first cycle. Then, he expressed the enabling side of the cooperation for the activities after the second (*f*=1) and the third (*f*=1) activities again. However, he did not say anything on the same issue during the interview of Activity-4 in this cycle. Similarly, he did not comment on the cooperation as an enabler during the interview of Activity-2 in the second cycle. In contrast, he expressed it as an enabler during the interview of Activity-1 (*f*=2), Activity-3 (*f*=1), and Activity-4 (*f*=1) in this cycle.

According to the teacher, *cooperation* was provided via *the adoption of the students into their groups.* This cooperation gave them the chance to interact with others more and then produce something together. He described this interaction within the group during one of the interviews of the activities as in the following:

C1_A2_T: Through the interaction within groups, the students recognize themselves and the other friends. They produce something together.

C1_A2_T: Hani çocuklar bu grup içi etkileşimi yaparak hem kendilerini tanıyorlar hem diğer arkadaşlarını tanıyorlar. Beraber bir şeyler üretiyorlar.

Forming Groups

In group works of the activities, *forming groups* was found as one of the enablers of the process according to the findings of the current study. In point of fact, the groups were formed at the beginning of the activities in two different ways for two cycles of study. In one of them, the students in the first cycle formed their groups *voluntarily*. On the other hand, the researcher and the teacher influenced the form of groups taking students' background information into account in the second cycle. Students were divided into three groups based on their previous year grades in Science, ITS, and Turkish Courses firstly. Students' names were printed on the cards, which were in different colors according to their background information. Then, the teacher gave the students' cards, and they were free to set their own groups. The rule was that groups had to contain all but different colors of cards. Therefore, students did not totally but instead *partially volunteer* to form their groups in this cycle.

In one of the classrooms in the second cycle, there was a compulsory student exchange between the classrooms after the first activity. In this process, five students exchanged with students in another classroom based on administrative reasons. When the new students came to the activity classroom, they were put into empty groups. However, after the second activity, several problems emerged with these groups. Therefore, in the third activity, the groups were updated again. In this second composition, the students *voluntarily* formed their groups in that classroom as the students in the first cycle.

According to the findings provided in Table 4.14, *forming of groups* as an enabler was expressed by the teacher only during the interviews of Activity-1 (*f*=1) and

Activity-3 (*f*=1) in the first cycle. Similarly, in the second cycle, he referred to it only during the interviews of Activity-1 (*f*=2) and Activity-4 (*f*=4).

In one of the interviews, the teacher expressed the positive effect of forming groups in a *partially volunteer* way. According to him, the assignment of the group members to the students was rewarding, especially when the students had not met before as the students in the second cycle. The students in this cycle were not together in the previous year. The classes in this cycle were combined due to the insufficient number of students in the previous year. The teacher commented on the method of forming groups here as follows:

> *C2_A1_T: At this point, it is better not to leave the groups completely to the students, especially to the new students who have a new environment with friends.*

> *C2_A1_T: Bu noktada hani grupları tamamen öğrencilere bırakma özellikle de yeni bir arkadaş ortamı olan yeni tanışan öğrencilerde grupları tamamen onlara bırakmamak daha iyi.*

In the first cycle, in which groups were formed voluntarily, it was observed that the students established the division of labor in group works. In the focus group interviews, they expressed that this adjustment was made in the groups because of the limited time of the activities. Therefore, for the second cycle, a modification for the forming group was made and the students were encouraged to separate the group works and assign them according to *the division of labor* in this cycle. This adjustment on groups was considered one of the enablers of the activities by the students. One of them commented on the division of labor for the activities to proceed comfortably as follows:

> *C2_A2_S2: We have distributed the labor during the activity and constructed the robot easily.*

> *C2_A2_S2: Etkinlikte görev dağılımı yaptık ve rahatça robotu yaptık.*

The adjustment on division of labor and other issues concerning *forming groups* was described as one of the enablers of the activities by the students during the data collection process several times. As the findings in Table 4.14 indicated one of the students described forming groups as an enabler during the interviews of Activity-1 (*f*=2) firstly. Another one described it again during the focus group meeting conducted after Activity-2 (*f*=1) in the first cycle. Similarly, the enabling side of forming groups was described by only one of the interviewed students at early activities (including Activity-1, *f*=1, Activity-2, *f*=1).

Solution Strategies

When the students were working in groups, they developed several solution strategies to overcome the faced challenges during the activity process. The utilized solution strategies that enabled the students to continue the process were found as one of the enablers of the problem-solving activities in the current study. As they were displayed in Table 4.15, the types of these solution strategies were trial and error, imagination, consensus, and collaboration, respectively.

Table 4.15 Frequency Distribution of Codes belongs to Category of Solution Strategies

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Trail & Error	-	3 (*n*=2)	-	2 (*n*=2)	1	4 (*n*=3)	-	2 (*n*=1)
	Imagination	2	4 (*n*=3)	-	2 (*n*=2)	-	-	-	-
	Consensus	-	1 (*n*=1)	-	2 (*n*=2)	-	1 (*n*=1)	-	1 (*n*=1)
	Collaboration	1	-	-	1 (*n*=1)	-	-	-	1 (*n*=1)
Cycle 2	Trail & Error	-	1 (*n*=1)	-	-	-	2 (*n*=2)	-	-
	Imagination	-	-	-	2 (*n*=2)	-	-	-	-
	Consensus	-	2 (*n*=2)	-	2 (*n*=2)	-	-	-	-
	Collaboration	-	2 (*n*=2)	-	-	-	-	-	2 (*n*=2)

*n *refers to the number of students responsible for the verbal occurrences within interviews*

Trial and Error

The findings provided in Table 4.15 revealed that the students expressed the use of solution strategy, *trial and error*, more frequently than the teacher during the data collection process. In detail, at the beginning of the implementation, the majority of the interviewed students (*f*=2) reported the use of this strategy to overcome the troubles they faced during the Activity-1 (*f*=3). Similarly, another interviewed two students after the second activity (*f*=2) described reported using trial and error solution strategy as one of the enablers of the activity process. Then, it was mentioned by three interviewed students during the focus group meeting conducted after Activity-3 (*f*=4). Additionally, one of the interviewed students referred to this enabler two times during the last focus group meeting at the end of this cycle. In the second cycle, the use of this solution strategy was reported by a total of three students who participated in the focus group meeting of the first activity (*n*=1, *f*=1) and the third activity (*n*=2, *f*=2).

Based on the findings mentioned above, the students usually used the solution strategy of *trial and error* when they experienced *a technical problem* in the programming or production phases. According to them, utilizing this method worked well and helped them to continue their activity properly. One of them commented on the challenge that they tackled during the programming phase and the use of trial and error as in the following:

> *C2_A3_FG5_S1: Teacher, if it is set as 20 and opened, the buzzer was ringing. We set as 21 then 22. We made like that and when it was 27, it was correct. I mean it goes here and when it detects, it stops and the buzzer rings.*

> *C2_A3_FG5_S1: Hocam, 20 yapınca direk açınca siren çalıyordu. 21 yaptık. 22 yaptık. Öyle öyle yaptık 27 de doğru oldu. Yani gidiyo burdan algılayınca da duruyo sireni çalıyo.*

Like the quotation of S1 above, the teacher mentioned that the students utilized the solution strategy of *trial and error* in *the programming phase* of the activity. He expressed the use of this strategy only during the interviews of Activity-3 (*f*=1) in the first cycle. According to him, the students used this strategy in the programming stage to find the correct way of programming the robots by saying the following:

> *C1_A3_T: They wrote the algorithm in the coding section, but while they were transferring it to the idea(editor), we had groups that had several trails.*
>
> *C1_A3_T: Kodlama bölümünde hani algoritmayı yazdılar ama hani onu ideaya geçirirken hani bir kaç deneme yapan gruplarımız oldu.*

Imagination

The students also talked about how they solved the problems for *making sense of the problem statement* during the activity process. Some of them argued that they eliminated the weak solution proposals via *imagination*. In this strategy, students usually tried to *foresee the results of their solution* before acting with it. One of the students commented on the usage of this strategy as follows:

> *C1_A2_FG2_S1: For example, we imagined how it might be. Then we thought it might be.*
>
> *C1_A2_FG2_S1: Mesela hayalettik yani nasıl olabilir diye düşündük. Sonra olabileceğini düşündük.*

According to the findings presented in Table 4.15, the students expressed the use of *the imagination* strategy during the interview of three different activities in both cycles. In the first of these, all the interviewed students expressed that they used this solution strategy during the interview of Activity-1 (*f*=4) in the first cycle. Then, two students descried their solution strategies as the use of the imagination during the focus group meeting of Activity-2 (*f*=2) in this cycle. In the second cycle, for the same activity again, two students mentioned it (*f*=2) one more time.

The findings in Table 4.15 indicated that the teacher also described that the students used the *imagination* as a solution strategy during only the interviews of Activity-1 (*f*=2) in the first cycle. According to him, this activity had a problem area in which students were expected to behave like engineers in a robot factory. The students were seen as using this strategy in this activity when he asked them. He reported it as in the following:

> *C1_A1_T: While the students were writing the problem on their own when I asked what they understood, they said the customers were dissatisfied so they wanted a different robot. The students felt they were working there.*
>
> *C1_A1_T: Problemi yazarken kendileri yazarken hani ne anladınız dediğimde müşteriler işte memnun değiller farklı bir robot istiyor. Hani çocuklar orada kendileri çalışıyormuş gibi gördüler.*

Consensus

Consensus, another type of solution strategywas described by only the students during the data collection process, according to the findings presented in Table 4.15. In the first cycle, some of the interviewed students expressed the use of this strategy throughout the implementation process. In detail, at the beginning of the implementation, one of the interviewed students reported that the use of consensus as a solution strategy for faced troubles the first time (*f*=1). Next week, two of the interviewed students expressed it again (*f*=2). Then, one student participating in the remaining activities commented on this enabler separately in this cycle (including Activity-3, *f*=1, Activity-4, *f*=1). In the second cycle, all descriptions on the consensus as a solution strategy belonged to interviewed two students after Activity-1 (*f*=2) and the other two interviewed after Activity-2 (*f*=2).

The students above explained the use of this solution strategy that they usually tried to *achieve consensus* when the group members had different opinions on a specific topic. *Finding the most appropriate solution offer* was one of these topics. In Cycle-

2, one of the students defined the use of this strategy to find the best solution offer for their groups in the reflection paper as the following:

> *C2_A2_R_Fatma: Everyone has different solution offers and we try to find a good idea by bringing them all together.*

> *C2_A2_R_Fatma: Herkesin farklı çözüm önerileri oluyor ve biz hepsini bir araya getirerek güzel bir fikir bulamaya çalışıyoruz.*

Collaboration

The aforementioned strategies were mostly applied by the students cooperatively during the activity process. In addition to this, some of the students and the teacher separately reported *the collaboration* as one of the solution strategies independently. According to them, the students handled several problems collaboratively to go on the activity process. The teacher expressed the use of *collaboration* for the solution of problems during the activities for only Activity-1 (*f*=1) of the first cycle based on the findings provided in Table 4.15. In this activity, he commented on how he suggested the use of collaboration as a solution strategy for one of the groups as follows:

> *C1_A1_T: When I talked to other students in the group, I progressed with problem-solving. By saying that they can do it all together, these are the ingredients, and that they can give their friends a task, they continued to do it with their friends who thought that he/she was not doing anything there.*

> *C1_A1_T: Gruptaki diğer öğrencilerle konuştuğumda sorun çözme yoluna gittim. Orada da hani çocuklarla konuşarak hep beraber yapabileceklerini,malzemelerin bunlar olduğunu, arkadaşlarına da bir görev verebileceklerini söyleyerek diğer kenarda olduğunu bir şey yapmadığını düşünen arkadaşlarıyla beraber yapmaya devam ettiler.*

The findings in Table 4.15 revealed that the students also described the use of *collaboration* as a solution strategy during the data collection. In detail, one of the interviewed students after Activity-2 (*f*=1) and Activity-24(*f*=1) expressed the employment of collaboration as the solution method of troubles in the first cycle. Similarly, two of the interviewed students mentioned the use of it for only Activity-1 (*f*=2) and Activity-4 (*f*=2) in the second cycle. One of the students expressed the use of this solution strategy on the reflection paper as in the following:

> *C2_A1_ FG2_S4: We got together with my friends, so we worked together and coped with difficulties.*
>
> *C2_A1_FG2_S4: Arkadaşlarımla beraber birlik olup yani birlikte çalışıp zorlandığımız şeyleri atlattık.*

The collaboration expressed by S4 occurred as *getting help from others* to handle the problems during the activities. In this strategy, the students asked others about the problem itself. Then, they got help from others to overcome that problem directly. The others differed here from the students to the teacher and the researcher in this strategy. One of the students expressed the sources of help for the troubles in the programming phase as follows:

> *C2_A1_R_S6: I had trouble in some steps of programming. I asked for help from my friends and my teacher.*
>
> *C2_A1_R_S6: Programlamakta bazı yerlerde zorlandım. Arkadaşlarımdan ve de öğretmenimden yardım istedim.*

Effective Communication

The observations prior to the activities indicated that the students were in a positive atmosphere in their classrooms in both cycles. The students could easily ask questions to their teachers, and their communication among other friends was very well in this atmosphere. This effective communication continued during the activities. Since the students were highly active in small groups, they were in interaction with group members, other groups, the teacher, and the researcher. In accordance with the observations before and during the activities, this effective communication was divided into two types: in-activity and out-of-activity communication, based on the findings provided in Table 4.16.

Table 4.16 Frequency Distribution of Codes belongs to Category of Effective Communication

	Codes/**Participants**	**Activity 1** **T**	**S**	**Activity 2** **T**	**S**	**Activity 3** **T**	**S**	**Activity 4** **T**	**S**
Cycle 1	In-Activity	4	7 (*n*=3)	2	-	6	2 (*n*=2)	2	-
	Out-of-Activity	3	-	-	-	1	-	-	-
Cycle 2	In-Activity	2	-	-	1 (*n*=1)	-	3 (*n*=2)	1	-
	Out-of-Activity	-	-	-	-	-	-	-	-

*n *refers to the number of students responsible for the verbal occurrences within interviews*

In-Activity Communication

The findings of the current study indicated that *communication in-activity* was one of the instructional and educational enablers of the activities. This kind of communication appeared as *intergroup* and *intragroup interactions* during the activities. To give more details, the students highly interacted with others who were in their own groups as expected. Additionally, they were also in effective communication with other groups in the problem-solving process. The teacher expressed positive opinions on effective communication in the activities during the interviews of activities. The findings provided in Table 4.16 revealed that he described these in-*activity communication* styles as an enabler for all the activities throughout the first cycle. Most of his descriptions were collected during the interview of Activity-3 (*f*=6) in the first cycle. The frequency of his descriptions on effective communication in activities during the activities of Activity-1 (*f*=4), Activity-2 (*f*=2), Activity-4 (*f*=2) was quite lower than the third activity in this cycle. In the second cycle, he expressed the effective communication in activities as an enabler during the interviews of Activity-1 (*f*=2), and Activity-4 (*f*=1). One of these interviews, the teacher expressed effective inter and intragroup communication during the activity process.

> *C1_A1_T: There was no problem between the groups. Intergroup communication was good, and it was also good among groups.*

C1_A1_T: Gruplar arasında bir sorun olmadı. Hani grup içi iletişim iyiydi ve gruplar arasında da iyiydi.

The findings related to the students indicated that they also mentioned *in-activity communication* as an enabler for the activities. According to the data in Table 4.16, all the interviewed students in the first activity reported their communication in activities as one of the enablers at the beginning of the implementation (*f*=7). Similarly, two interviewed students described the communication during the activities as an enabler during the focus group meeting of the third activity (*f*=2) in the first cycle. In the second cycle, only one of the interviewed students defined it during the interview conducted after the second activity (*f*=1), and two others during the focus group meeting of Activity-3 (*f*=3).

Additionally, one of the students implied effective communication during the activities in the drawing paper. In the explanation of this drawing, the student claimed that she was introducing the robot to the teacher with other group members at a table. This drawing (Figure 4-6) and the supported text are in the following:

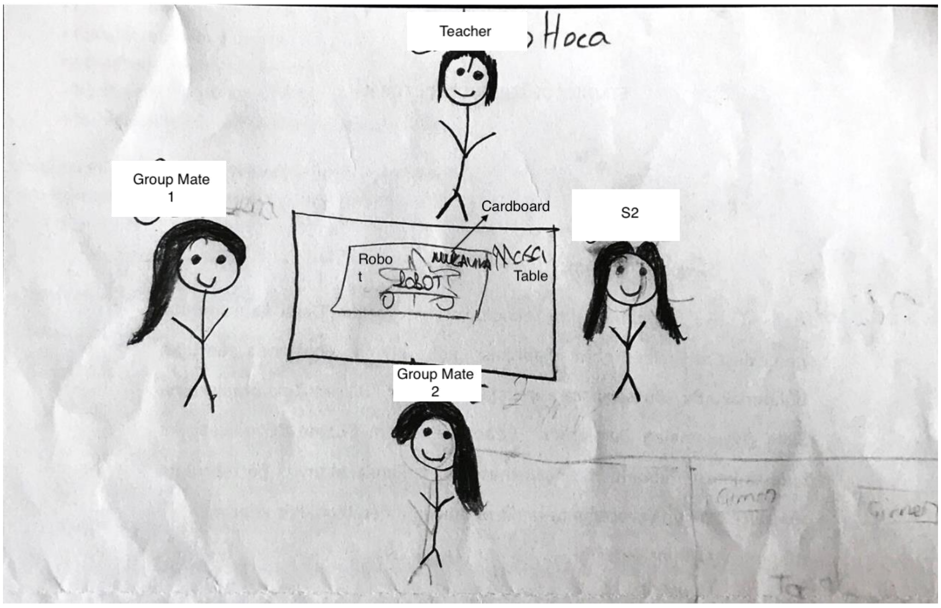

Figure 4-6 Drawing of S2

C2_A2_D_S2: We were telling our teacher how we made our robot, what materials we used. Our teacher was listening to our explanations, as well.

C2_A2_D_S2: Biz öğretmenimize robotumuzu nasıl yaptığımızı, hangi malzemeleri kullandığımızı anlatıyoruz. Öğretmenimiz de bizim anlattıklarımızı dinliyor.

Out-of-Activity Communication

According to the teacher, apart from the effective communication during the activities, *out-of-activity communication* was also a crucial enabler for the progress of the activities properly. For instance, *the friendship* between the students in the classroom eased the whole process and affected the activities positively. It was obvious in the findings provided in Table 4.16 that all the descriptions for the *out-of-activity communication* belonged to the teacher. These descriptions were collected from him only during the Activity-1 (*f*=3) and Activity-3 (*f*=1) interviews in the first cycle. In one of these interviews, the teacher commented on this enabler as in the following:

C1_A3_T: The good communication among the students in the classroom affected the process positively.

C1_A3_T: Çocukların iletişimlerinin, sınıf içerisindeki iletişimlerinin iyi olması süreci olumlu yönde etkiledi.

Essence of Activity

In addition to all the aforementioned enablers, *the essence of the activity* was the last educational and instructional enabler of the activities. This category resulted from the unique features of the activities. According to the findings provided in Table 4.17*, the time of activities,* and *the problem scenario* presented in the activity sheet were these features of activities. It was also apparent in the findings that only the teacher commented on these features.

Table 4.17 Frequency Distribution of Codes belongs to Category of Essence of Activity

	Codes/**Participants**	**Activity 1**		**Activity 2**		**Activity 3**		**Activity 4**	
		T	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Activity Time	4	-	3	-	3	-	2	-
	Problem Scenario	6	-	2	-	2	-	1	-
Cycle 2	Activity Time	4	-	-	-	1	-	4	-
	Problem Scenario	-	-	-	-	-	-	-	-

*n *refers to the number of students responsible for the verbal occurrences within interviews*

Activity Time

The findings in Table 4.17 indicated that the teacher described *the activity time* as an enabler for the activities during all the activities in the first cycle. In detail, he described the time of the activity as one of the enablers during the interview of Activity-1 (*f*=4), firstly. In the interview of the next two activities, he reported it again (*f*=3). Lastly, he described the time of the activities as one of the enablers of the activity at the end of the implementation (*f*=2) in this cycle. In the second cycle, the frequencies of his descriptions were equal for Activity-1 (*f*=4) and Activity-4 (*f*=4). Moreover, he described the time of the activities as enabler during the interview of the third activity (*f*=1).

In those interviews, the teacher expressed that *the sufficiency of time* to complete the activities was an enabler of the process. According to him, the groups could complete the activity in time since they had sufficient time to do all their work on time. Additionally, *the schedule* of the activities was very appropriate for the implementation process. The hours of activity were overlapped on the course schedule. Therefore, the students found the opportunity to go on their works without any interruption. According to him, this schedule of activity eased the activity process by saying the following:

> *C1_A1_T: Its succession made it easier for us. You know, if it had spread to different times on different days, things would have been left unfinished and*

we would have had to go back to the beginning. We would have gave reminders, but there was no need for that. They completed it in four lessons in a day.

C1_A1_T: Ard arda olması etkinliğimizi kolaylaştırdı. Hani farklı günlerde, farklı saatlere yayılmış olsaydı yapacağımız şeyler yarım kalacaktı ve tekrar başa dönecektik. Hatırlatmalar yapacaktık ama bunda öyle bişeye gerek kalmadı. Bir günde dört ders saati içerisinde tamamlamış oldular.

Problem Scenario

The problem scenario developed for the activities was also considered as an enabler of the activities by the teacher. *The comprehensibility of the problem statement* and its high *relation with the context* were the key points of this decision. The findings in Table 4.17 showed that he commented on this enabler only during the interviews of the first cycle. He referred to it during Activity-1 (*f*=6) quite more frequently than other activities in this cycle. During the interviews of the next two activities, he expressed the scenario of the activity as one of the enablers of the activities again (*f*=2). Then, he alluded to it one more time after the last activity (*f*=1) in this cycle. During one of these interviews, the teacher commented on the problem scenario that eased the activity process as in the following:

C1_A2_T: Without the scenario, the problem would be in the air, that is when we asked the children directly. The scenario contributed to children in generating even more diverse ideas in their minds.

C1_A2_T: Senaryo olmadan bu problem havada kalıcaktı, yani düz bir şekilde çocuklara sorduğumuz zaman. Senaryonun bize zihinlerinde daha da çeşitli fikirler üretme noktasında katkısı oldu.

Facilities

The findings gathered throughout the data collection and analysis phases of the current study revealed that *the facilities* were the other theme of enablers for problem-solving activities in addition to *learning and instructional enablers*. These facilities were grouped under two categories named as the *utilization of resources* and *school facilities*. The theme and related categories were presented in Figure 4-7.

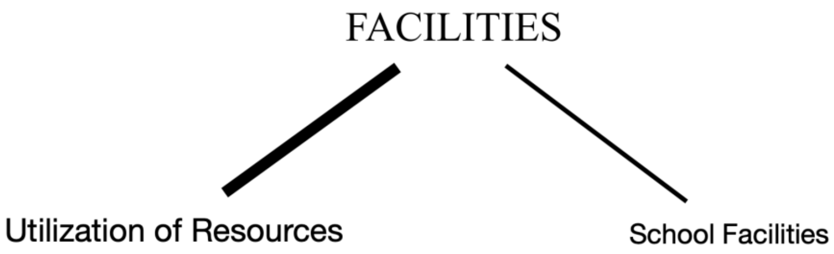

Figure 4-7 Categories of Facilities Theme

The main data sources for these categories were the interviews with the teacher and the students in both cycles of the implementation. A code tree which included categories of the theme and the related codes listed from most cited to least one by the participants during the interviews presented in Table 4.18. Each category and the related codes of the facilities in activities were elaborated one by one after this illustration.

Table 4.18 The Code Tree of Facilities Theme

Categories/Codes	Σf
Utilization of Resources	**132**
Technological Resources	51
Activity Sheet	45
Stationery Materials	36
School Facilities	**21**
Number of Students	11
Structural Opportunities	10

Utilization of Resources

The utilized resources by the students during the activities were clustered in *technological resources, activity sheet, and stationery materials* based on the data analysis. According to the majority of students and the teacher, the use of these resources had a positive effect on the progress of activities. The frequency distribution of these resources for each activity in two cycles was presented in Table 4.19.

Table 4.19 Frequency Distribution of Codes belongs to Category of Utilization of Resources

		Activity 1		Activity 2		Activity 3		Activity 4	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Technological Resources	7	4 (*n*=2)	5	4 (*n*=2)	3	-	2	7 (*n*=2)
	Activity Sheet	-	6 (*n*=3)	7	2 (*n*=1)	2	14 (*n*=3)	-	-
	Stationery Materials	3	4 (*n*=3)	-	3 (*n*=1)	3	7 (*n*=5)	1	-
Cycle 2	Technological Resources	4	4 (*n*=4)	2	1 (*n*=1)	2	2 (*n*=2)	3	1 (*n*=1)
	Activity Sheet	2	1 (*n*=1)	-	2 (*n*=2)	2	2 (*n*=2)	5	-
	Stationery Materials	-	6 (*n*=5)	-	5 (*n*=4)	-	-	-	4 (*n*=3)

**n refers to the number of students responsible for the verbal occurrences within interviews*

Technological Resources

The use of *technological resources* as an enabler was expressed by the teacher during the interviews of all activities. The frequency of his comments on the use of these resources was quite high at the beginning of the implementation in the first cycle (Activity-1, *f*=7). According to the findings provided in Table 4.19, this frequency declined gradually throughout the following weeks of the implementation of this cycle (including Activity-2, *f*=5, Activity-3, *f*=3, Activity-4, *f*=2). In the second cycle, the teacher described these resources as a facilitative enabler during the interview of first activity (*f*=4) firstly. Then, he repeated the similar expressions for these resources next two activities with the same frequency (*f*=2). At the end of the implementation, he described technological resources as one of the enablers of the activities one more time (*f*=3).

The infrastructure of the laboratory was one of the technological resources used by the students during the activities. *The computers* in the laboratory, which were highly qualified and compatible with each other, seemed as one of the other facilitative enablers of the activities by the teacher. For instance, he expressed the benefits of the infrastructure of the laboratory for the process of the first activity in the first cycle by saying the following:

> *C1_A1_T: Technical infrastructure and computers at a good level were beneficial for the process.*
>
> *C1_A1_T: Teknik altyapı ve bilgisayarların iyi olması, iyi düzeyde olması, sürece faydalı oldu.*

Besides, *the use of robots* was defined as the other facilitative resource of the activities by the teacher many times (*f*=8). In one of those expressions, he underlined the importance of the robots *to concretize the solutions* during the activity process as follows:

> *C1_A3_T: Of course, in the activity here, all groups have already coded educational robots. By using robots and sensors, they developed solutions to the problem situation. Without educational robots, children would still be able to say something about things, they could imagine, they could tell their dreams, but they saw something concrete by using educational robots, and it made them happy, so it provided a more positive effect.*
>
> *C1_A3_T: Tabi buradaki etkinlikte eğitsel robotların tüm gruplar zaten kodlamasını yaptılar. Algılayıcıları kullanarak, eğitsel robotları kullanarak problem durumuna çözüm önerisi geliştirdiler. Eğitsel robotlar olmasaydı çocuklar şeyler hakkında yine bir şeyler söyleyebileceklerdi, hayal edebileceklerdi, aklından geçen hayalleri söyleyebileceklerdi ama eğitsel robotları da kullanarak somut bir şey görmüş oldular ve işe yarayacak çözüm önerilerini de somut bir şekilde görmüş olmaları onları mutlu etti ve daha da olumlu yönde bir etki sağladı.*

Similar to what the teacher said, the students reported that the use of *well-equipped laboratories* and *robots* had a positive effect on their problem-solving process. These facilities specifically eased the activity process for them. One of the students expressed this effect for the high-qualified robot kits as in the following:

C1_A2_FG2_S1: For example, the high quality of the robots eased our works.]

C1_A2_FG2_S1: [Bizim işlerimizi kolaylaştıran robotların şey olması kaliteli olması mesela işimizi kolaylaştırdı.

According to the frequency distribution of the students' descriptions in Table 4.19, two different students reported the use of these *technological resources* during the interview of Activity-1 (*f*=4), Activity-2 (*f*=4), and Activity-4 (*f*=7) in the first cycle of the implementation. In the second cycle, four interviewed students expressed the use of technical resources as an enabler for Activity-1 (*f*=4) at the beginning of the implementation. Then, another one described these resources as an enabler of the activities during the interview of Activity-2 (*f*=2). Similarly, these resources were one of the facilitative enablers of the activities for two students in the third activity (*f*=2). At the end of the implementation, only one of the interviewed students commented on the technological resources as an enabler of the activities lastly (*f*=1) in this cycle.

Activity Sheet

Apart from the technological resources, *the activity sheet* was another facilitative enabler of the activities, according to the participants. In fact, this sheet was developed by the researcher to provide the students with *a path to follow ill-structured problem solving-process* in the activities. One of the examples of the sheet is presented in Appendix K.

The findings in Table 4.19 demonstrated that the students started to express the facilitative aspect of *activity sheet* during the focus group of the first activity (*n*=3, *f*=6). Next week, only one of the interviewed students described this resource as one of the enablers (*f*=1). Then, three students expressed that the activity sheet eased the activity process (*f*=1) last time in the first cycle. In the second cycle, the activity sheet was described as one of the facilitative enablers by one student after the first activity (*f*=1) firstly. During the focus group meeting in next two activities, two students expressed the facilitative aspect of the activity sheet for the activities lastly (*f*=2) in this cycle. Among those interviews, two students commented on the use of the activity sheet during the focus group meetings as follows:

> *C1_A2_FG2_S2: For example, it was written there as: "What equipments will you use?". We separated them one by one and then looked at it (activity sheet) in the algorithm, too. We looked at the sheet while creating the algorithm.*
>
> *C1_A2_FG2_S2: Mesela orada yazıyordu "Hangi eşyaları kullanacaksınız?" diye. Biz onları tek tek ayırdık ve sonra algortimada da ona baktık. Algortimayı oluşturuken kağıda baktık.*
>
> *C1_A2_FG2_S1: It may have contributed to us that it might be more difficult to think of the problem instead of writing it on sheet. It is better to write. Some of them might slip out of our minds then, but when we write, nothing slips off our minds.*
>
> *C1_A2_FG2_S1: Bize problemi mesela kağıda yazmak yerine düşünmek daha zor olabilir diye bir katkısı olmuş olabilir. Yazmak daha iyi. Bazıları şey sonra aklımızdan çıkıyo ama yazınca hiç bir şey aklımızdan çıkmıyo.*

Similarly, *the activity sheet* was claimed to be one of the enablers by the teacher for the majority of activities. In the first cycle, he described this facilitative resource as an enabler during the interviews of Activity-2 (*f*=7) firstly. Then, he repeated this aspect of the activity sheet two times during the interview of Activity-2 (*f*=2). In the second cycle, the activity sheet was defined as one of the enablers of the activity process by the teacher after the first activity for the first time (*f*=2). Likewise, he commented on the use of activity sheet as one of the enablers of the activities during the interview of the third activity (*f*=2). Lastly, he expressed it for the Activity-4 (*f*=5) in this cycle, according to the findings in Table 4.19. For one of those activities, he mentioned the effect of the activity sheet on the activity process by saying the following:

> *C2_A4_T: Yes, when they fill the activity sheet, the experience becomes concrete. Otherwise, we did not try that style directly, I did not try it, so we could give the problem directly without filling the activity sheet, but then some things could stay in the air .... I cannot make a full comparison right now, but I think they will have more difficulty or they could not find an effective solution. At this point, the activity sheet has a major impact.*

> *C2_A4_T: Evet yani etkinlik kağıdını doldurdukları zaman olay somutlaşıyor. Diğer türlü de o tarz direkt olarak denemedik, denemedim yani etkinlik kağıdını doldurmadan direkt problemi verip de yapabilirlerdi ama o zaman bazı şeyler havada kalabilirdi....Tam kıyaslama yapamayacağım şu anda ama daha zorlanacaklarını ya da daha etkili çözüm bulamayacaklarını düşünüyorum ben etkinlik kağıdının bu noktada büyük bir etkisi var.*

Stationery Materials

The students utilized *the stationery materials* during the design stage of the activities. It was observed during the activities that some of these materials were used for *simulation of the solutions*. However, in some cases, these materials were one *part of the solution*, and without these materials, the solution was pointless. Regardless of these purposes of use, the participants reported that these materials were one of the facilitative enablers of the activities.

The findings of the current study presented in Table 4.19 indicated that the teacher mentioned *the use of stationery materials* as an enabler of the activities during the interview of Activity-1 (*f*=3), firstly. Then, he referred to this enabler after Activity-3 (*f*=3) and Activity-4 (*f*=3) in the first cycle. He did not report anything about the facilitative aspect of these materials in the second cycle's activities. During the interview of Activity-1 in the first cycle, he commented on the positive aspect of these materials as they separated the activities from casual course hours by saying the following:

C1_A1_T: Also, the stationery materials are very positive. I can say that their use is effective. So if they weren't there, the student would also code it but it would be similar to what we have seen in our previous lessons.

C1_A1_T: Ondan sonra o yardımcı malzemeler çok olumlu. Kullanımlarının etkili olduğunu söyleyebilirim. Yani onlar olmasaydı, çocuk hani kodlayacaktı, yani bir önceki derslerimiz de gördüğümüzün benzeri şeyleri olacaktı.

The findings with regard to the students provided in Table 4.19 showed that all the interviewed students in the first activity of the implementation reported the stationery materials as one of the enablers of the activities(*f*=4). Then, only one student expressed it during the focus group meeting of the next activity (*f*=3). The remaining descriptions on the use of these resources belonged to five students after the third activity (*f*=7) in the first cycle. Five students after the first activity in the second cycle also described these resources as enabler (*f*=6). Similarly, other four and three students mentioned that the stationery materials were the enablers of the activities during the focus group meeting of Activity-2 (*f*=5) and Activity-4 (*f*=4), respectively.

According to these students, especially *the delivery method of stationery materials*, which was based on a lot, eased the activity process. In fact, the delivery method of these materials was an essential problem during early activities. They were given to the groups one by one. However, the majority of the students were not happy with this distribution. Therefore, the distribution method was replaced by a new one havinga system based on lots. In this method, students were required to select an order number from closed postcards. Then, the stationery materials were given to them according to the order of the number which they got from the lot. The students expressed this distribution method as an enabler of the activities in addition to the use of stationery materials. Two of the students expressed these enablers as follows:

C2_A1_FG3_S2: Stationery materials as well. The stationery materials made our work easier.

C2_A1_FG3_S2: Malzemeler bir de. Malzemeler işimizi kolaylaştırdı.

C1_A3_FG3_S1: Then now when you draw lots, when we start to take such things one by one, the order has found its place.

C1_A3_FG3_S1: Sonra şimdi siz kura falan çekince, böyle teker teker almaya başlayınca o düzen yerini buldu.

School Facilities

The findings of the current study displayed that *the school facilities* were another enabler of the ill-structured problem-solving activities. In detail, *the number of students* in classrooms and *structural opportunities* of the school were found as school facilities based on the analysis of the data gathered from the participants. The codes of the category and their frequency distribution of these findings were presented in Table 4.20.

Table 4.20 Frequency Distribution of Codes belongs to Category of School Facilities

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Number of Students	1	-	-	-	2	1 (*n*=1)	-	-
	Structural Opportunities	-	-	-	-	-	-	-	-
Cycle 2	Number of Students	1	-	-	-	2	-	3	1 (*n*=1)
	Structural Opportunities	-	-	-	1 (*n*=1)	-	1 (*n*=1)	7	1 (*n*=1)

*n *refers to the number of students responsible for the verbal occurrences within interviews*

Number of Students

The finding indicated that *the number of students* in activities, which referred to both *the classroom size* and *the number of students in groups*, made the activities quite easy. Both the students and the teacher described this facility as an enabler of the activity process based on the data in Table 4.20. The teacher commented on the number of students as an enabler three times in the first cycle during the interview of Activity-1 (*f*=1) and Activity-3 (*f*=2). Similarly, he expressed the enabler during the interview of the first activity (*f*=1) and the third one (*f*=2) in the second cycle. Additionally, he mentioned the number of students as one of the enablers of the activities after the last activity (*f*=3) in this cycle. In one of these activities, the number of the students in classroom was reported as an enabler by him as the following:

> *C1_A3_T: In this event, besides, the low number of students made things a little easier.*

> *C1_A3_T: Bu etkinlikte farklı olarak öğrenci sayısının az olması biraz* daha *belki işleri daha da kolaylaştırdı.*

Several students had the same ideas with their teachers about their *numbers in classroom and groups*. The findings of them provided in Table 4.20 indicated that only one of them reported the facilitative aspect of their numbers during the focus group meeting of Activity-3 (*f*=1) in the first cycle. Similarly, only one interviewed students in different groups for Activity-3, Activity-4 in the second cycle (*f*=1) commented on the same enabler. One of the students commented on the group size including three students as an enabler of the activity and the effect of this on the work as follows:

> *C2_A4_FG1_S1: It was nice. We did it with S2 last week. It was a little difficult but it was more comfortable when one more person put his hand.*

> *C2_A4_FG1_S1: Güzeldi yani geçen hafta S2 ile yaptık o zaman biraz zordu ama bir kişi daha elini koyunca işe daha rahat oldu.*

Similarly, the teacher described the groups of three as an enabler of the activities. He commented on group size as follows:

> *C2_A4_T: Let me start with this class layout if you want. When grouping students, it is better to have groups of three, there may be some difficulties in grouping in four or in two.*

C2_A4_T: Önce isterseniz bu sınıf düzeninden başlayayım. Öğrencileri gruplandırırken üçerli gruplandırmanın daha iyi olduğunu, dörderli gruplandırma ya da ikişerli gruplandırmada biraz sıkıntılar olabilir.

Structural Opportunities

Structural opportunities were other facilities of the schools. The participants expressed this as one of the enablers during only the process of the second cycle based on the findings provided in Table 4.20. In detail, the only one of the interviewed students reported the structural opportunities of the school as an enabler during the focus group meeting of Activity-2 (*f*=1), Activity-3 (*f*=1), and Activity-4 (*f*=1) in this cycle. Similarly, the teacher only commented on them during the interview of Activity-4 (*f*=7).

According to the participants, *the availability of the laboratory* used for activities was one of the structural facilities of the school. The students could use this laboratory after the course hours. Therefore, this made it one of the enablers of the activities. Another structural facility of that school was *the availability of the library* in the implementation school. In some of the activities, the students used this library in the first stage of it to fill the activity sheet since the layout of it was more appropriate to perform group works. Hence, the participants thought that the use of this library was one of the structural facilities of the school that eased the activity process. The teacher and one of the students commented on the use of the laboratory in extra time and the use of the library during the interviews as in the following:

C2_A4_T: I think it is useful for us to use the laboratory to complete their unfinished activities.

C2_A4_T: Laboratuvarı kullanabilmelerinin yarım kalan etkinliklerini tamamlayabilmeleri noktasında bize faydasının olduğunu düşünüyorum.

C2_A3_FG5_S2: Nice to go to the library, teacher.

C2_A3_FG5_S2: Kütüphaneye çıkmamız güzel hocam.

Challenges of Problem-Solving Activities

Instructional Challenges

The challenges of the activities were also examined for the first sub-research question. Based on the data analysis results derived from the interviews with participants, the challenges of the activities were collected under two themes: "*instructional challenges*" and "*logistic challenges*". Other data sources of the study, which were the reflection papers, text supported drawings, and the activity sheets, also supported these themes. Among them, the instructional challenges of the activities were the barriers that were categorized as *group work problems, lack of readiness, time, goal orientation, motivation,* and *external challenges*. These categories were illustrated in Figure 4-8.

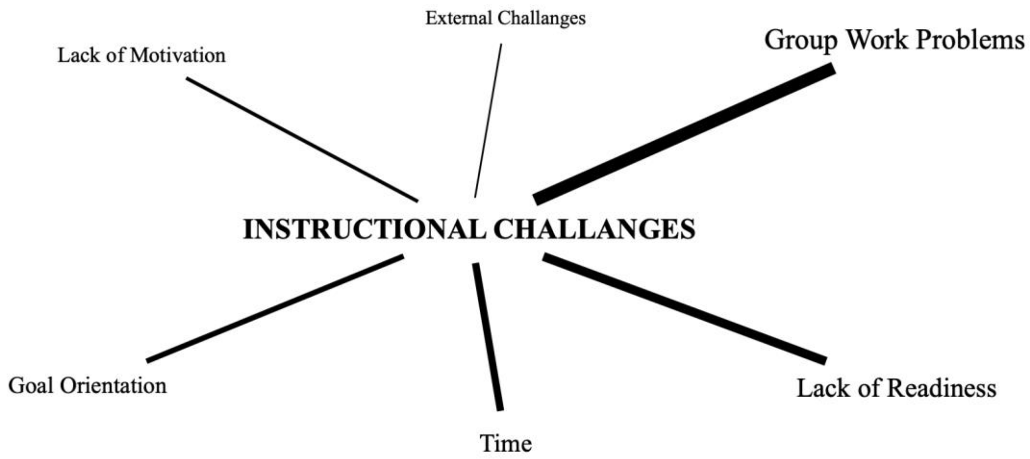

Figure 4-8 Categories of Instructional Challenges Theme

These categories and the related codes were given in Table 4.21 which included a code tree for the categories of the instructional challenges theme listed from most cited to least one by the participants. Each category and the related codes of the instructional challenges of activities were elaborated on one by one after the presentation of the table.

Table 4.21 The Code Tree of Instructional Challenges Theme

Categories/Codes	Σf
Group Work Problems	**64**
Intragroup problems	53
Intergroup problems	11
Lack of Readiness	**41**
Lack of pre-requisite	26
Misconceptions	10
Low success level	5
Time	**39**
Duration	20
Schedule	19
Goal Orientation	**22**
Expanding shift	13
Narrowing shift	9
Lack of Motivation	**15**
Emotional routers	9
Unwillingness in duty	4
Lack of video	2
External Challenges	**15**
Administrative challenges	8
Not being with family	4
Readiness of teacher	3

Group Work Problems

After the analysis of the data, it was found that the most frequently reported challenge was *the group work problems* for the activities. These problems were faced in two kinds during the implementation process. The findings provided in Table 4.22 revealed that the most frequently described group work problems were under the code of *intragroup problems*. However, the number of problems between groups named as *intergroup problems* was also considerable. The frequency distribution of the participants' descriptions on these two types of group work problems for activities were presented in Table 4.22.

Table 4.22 Frequency Distribution of Codes belongs to Category of Group Work Problems

	Codes/**Participants**	**Activity 1** **T**	**S**	**Activity 2** **T**	**S**	**Activity 3** **T**	**S**	**Activity 4** **T**	**S**
Cycle 1	Intragroup problems	4	6 (*n*=3)	6	-	1	1 (*n*=1)	-	1 (*n*=1)
	Intergroup problems	3	3 (*n*=2)	1	-	1	1 (*n*=1)	-	-
Cycle 2	Intragroup problems	3	9 (*n*=5)	1	10 (*n*=3)	1	5 (*n*=5)	2	3 (*n*=2)
	Intergroup problems	-	-	-	1 (*n*=1)	-	-	1	-

*n *refers to the number of students responsible for the verbal occurrences within interviews*

Intragroup Problems

According to the findings in Table 4.22, *the intragroup problems* were expressed by three interviewed students during the focus group meeting of Activity-1 (*f*=6) firstly in the first cycle. In contrast, they did not mention these problems for the Activity-2 in this cycle. The frequency of their descriptions concerning the intragroup problems was equal for the remaining activities in this cycle (*f*=1). In the second cycle, five interviewed students described this kind of problems as one of the challenges of the activities during the focus group meeting of the first activity (*f*=9). Similarly, in the next activity three interviewed students continued to explain these problems (*f*=10). The frequency of the students declined to five for the third activity (*n*=5) and three (*n*=2).

The findings presented in Table 4.22 indicated that the teacher also mentioned *the intragroup problems*. Like the frequency distribution of the students, he reported these problems in the first cycle more frequently during the interview of Activity-1 (*f*=4) and Activity-2 (*f*=6) in comparison to other activities. In this cycle, he did not mention any of the intragroup problems during the interview of Activity-4. Similarly, he expressed the most of these problems during the interview of first activity (*f*=3). He reported some of these problems only once for the second and the third activity (*f*=1) and twice during the interview of last activity (*f*=2).

These findings indicated that *the intragroup problems* were reported by the participants mostly during the first activities in both cycles and the frequency of reporting these problems decreased towards the last activities. The potential reasons for these findings were elaborated on in the discussion chapter of the study.

The intragroup problems were faced mainly as *group conflicts* during the activity process. This conflict resulted in *resentment* within groups and *negligence of the division of labor*. Additionally, *mobbing in groups* was another result of the conflict in group works. The mobbing was reported by the students as violence from other group members in some cases. These students committing violence prevented group members from doing their works and pressured them to leave the group, according to students affected by this mobbing. This exclusion of the group members was one of the barriers of activity process, as expressed by the teacher as follows:

> *C1_A1_T: Some of our students got angry with their friends during group interaction. I encountered problems such as thinking that I am not doing anything, or they are not taking me as long as they are not doing what I am saying. This was a situation that affected us negatively.*
>
> *C1_A1_T: Bazı öğrencilerimizin grup etkileşimi sırasında, arkadaşlarıyla küsme durumları oldu. Ben bir şey yapmıyorum gibi düşünmeleri, ya da sürece beni almıyorlar, benim dediklerimi yapmıyorlar şeklinde gibi sorunlarla karşılaştım. Bu bizi olumsuz etkileyen bir durum oldu.*

The disengagement from groups as *intragroup problem* was an important challenge of the activities. However, this disengagement was not only the result of conflicts between the students during the activities. In some cases, the students were not willing to participate in the group works. They usually desired to be in another group, or they were completely uninterested in activities. For instance, one of the students complained about the group members' irresponsibility on the work as in the following:

C2_A2_FG2_S1: It is going well, but sometimes there are situations that some friends do not help. For example, when the task distribution is done, somebody does not bring the objects.

C2_A2_FG2_S1: Güzel gidiyor ama bazen yardım etmediği yönleri oluyo bazı arkadaşların. Mesela biri görev dağılımı yaptığımızda eşyasını getirmiyor mesela.

Intergroup Problems

Beside the aforementioned intragroup challenges, *the intergroup problems* occurred during the activities. According to the findings in Table 4.22, these *intergroup problems* were described by two students during the interview of Activity-1 (*f*=3) firstly in the first cycle. Then only one of the interviewed students expressed them during the interview of the third activity in this cycle. In the second cycle, one of the students referred to the intergroup problems as one of the challenges of the activities for only Activity-2 (*f*=1).

According to the students, *the intergroup problems* were all about *the competitive interactions among groups* during the activities. Some of these interactions led to irreversible issues; for instance, the students in groups exposed to this interaction since they usually thought that they fell back from others. This resulted in a lower motivation level for those students. Therefore, these competitive interactions among the groups was an important challenge of the activities. One of the students described this challenge as the following:

C1_A1_FG1_S1: Teacher, I am so tired of such things: my friends came to us and said you could not do it, or you did the same so that would not work. It was too much.

C1_A1_FG1_S1: Hocam ben bir de şunlardan yoruldum arkadaşlarım gelip bize sen yapamadın, sen aynısını yaptın, bu olmaz. Öyle çok oldu.

The teacher also commented on the result of *competitive interactions*, which the students felt in a state of comparison arising from the interaction with others. He underlined that students, especially who finished later in stages of the activities, were demoralized very quickly during the problem-solving process as:

> *C1_A1_T: There were students who thought that they would not complete in time by looking at other groups. They told me that "Teacher, we are back. Other friends have already finished. They passed on to the coding section. We are still on fish bone section."They said they would not complete their work.*

> *C1_A1_T: Şimdi şöyle öğrencilerin diğer gruplara bakarak yetiştiremeyeceklerini düşünen öğrenciler oldu. Bunu bana söylediler. Hocam biz geri kaldık, diğer arkadaşlar bitirdiler. Kodlama kısmına geçtiler. Biz daha balık kılçığındayız şeklinde. Hani yetiştirmeyeceklerini söylediler.*

As the excerpt above, he expressed that *the intergroup problems* mostly accured during the interview of Activity-1(*f*=3) in the first cycle. Furthermore, he reported them as one of the challenges of the activities during the interview of Activity-2 (*f*=1) and Activity-3 (*f*=1) in this cycle. In the second cycle, he only mentioned one of these problems during the interview of last activity (*f*=1), according to the findings in Table 4.22.

Lack of Readiness

The finding of the current study revealed that *the lack of readiness* for the activities affected the activity process negatively. According to those findings, *the lack of prerequisites*, the *misconceptions*, and *low success level* caused this deficiency. Therefore, the students, who had some of these underlying factors, faced several difficulties during the activity process. These underlying factors and the frequency of the participants' descriptions on both factors were indicated in Table 4.23.

Table 4.23 Frequency Distribution of Codes belongs to Category of Lack of Readiness

	Codes/**Participants**	**Activity 1**		**Activity 2**		**Activity 3**		**Activity 4**	
		T	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Lack of pre-requisite	1	-	4	1 (*n*=1)	-	-	2	-
	Misconceptions	4	-	3	-	-	-	-	-
	Low success level	-	-	-	-	-	-	-	-
Cycle 2	Lack of pre-requisite	7	-	2	1 (*n*=1)	4	-	4	-
	Misconceptions	2	1 (*n*=1)	-	-	-	-	-	-
	Low success level	2	-	-	-	-	-	3	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Lack of Pre-requisite

According to the findings, the students who had not enough *prior knowledge* and *the required skills* for the activities often failed to complete the activity properly. This required knowledge was mainly *the corresponding subjects* with the activity. Moreover, *the knowledge base on the subjects of the previous year* also resulted in a lack of prerequisites. In addition to previous knowledge, the lack of required skills such as *working collaboratively*, *programming*, *problem-solving*, and *use of stationery materials* were other prerequisites, and these skills made the activity process difficult with their deficiency.

The findings provided in Table 4.23 revealed that *the lack of the prerequisites* was reported mostly by the teacher in the first cycle. He mentioned them firstly during the interview of Activity-1 (*f*=1) in this cycle. Then, during the second week interview, he reported the lack of the prerequisites as one of the challenges again (*f*=4). Last time in this cycle, he expressed the challenge one more time at the end of the implementation process (*f*=1). In the second cycle, the frequency of his descriptions concerning the lack of prerequisites was quite higher for Activity-1 (*f*=7) in comparison to other activities. During the interview of the second activity, he referred to the challenge again (*f*=2). In the remaining activities in this cycle, he mentioned the lack of the prerequisites as one of the instructional challenges with equal frequency (*f*=4). In one of those activities, he defined the lack of previous year knowledge based on problem-solving as a challenge of the activities. According to him, this deficiency was the reason why the activities could not be started immediately at the beginning of the semester. He commented as in the following:

> *C2_A4_T: In fifth grade lessons, the students were supposed to cover the subject of problem-solving, but they have not studied the subject since last year a teacher not from our field attended the lesson. They said they studied other classic subjects as fundamental Office Editors. We tried to create prior knowledge via the studies at the beginning of the semester. Yet, we could have started the activities directly.*

> *C2_A4_T: Bilgisayar dersindeki normalde beşinci sınıfta hani öğrencilerin bu konuyu görmeleri gerekiyordu, problem çözme konusu ama beşinci sınıfta kendi alanımızdan bir öğretmen derse girmediği için bu konuyu görmemişlerdi. Bilgisayar öğretmeni başka klasik konuları temel Office programlarını gördüklerini söylediler. Önbilgi olarak hani bu dönemin başında yaptığımız çalışmalarla önbilgiyi oluşturmaya çalıştık. Halbuki direkt olarak etkinliklere de geçilebilirdi.*

One of the interviewed students mentioned *the lack of prerequisites* as a challenge for the activities during the focus group meeting of Activity-3 (*f*=1) in the first cycle. Similarly, only one of them expressed the deficiency of prerequisites for the second activity (*f*=1), in the second cycle, based on these findings presented in Table 4.23. One of those students defined the deficiency of the ability to use the stationery materials as a challenge by saying the following:

> *C2_A2_FG2_S1: The things that make it difficult may be the tape because some do not know how to use double-sided tape since as you tear it up, it wrinkles immediately.*

C2_A2_FG2_S1: Zorlaştıran şeyler de belki bant olabilir başka taraflarda çünkü çift taraflı bant kullanmasını bilmeyenler. Onu koparıyosun ve hemen buruşuyor.

Misconceptions

Misconceptions on the subjects in both courses of *information technologies and software (ITS)* and *science* were another challenge about the readiness of the students during the activities. For instance, in the first activity, the students faced several troubles since they had misconceptions about the *subject of friction force*. Similarly, the *misconceptions on programming* the robots brought several challenges such as using the wrong sensors. In addition to misconceptions on the subjects, there were also misconceptions about filling parts in the activity sheet. For instance, several students were observed that they were writing the results of the ill-structured problem on the blank branches of *the fishbone* part of the activity sheet instead of the reasons. The the misconception of filling the activity sheet parts was described as in the following:

C1_A1_T: They just wrote the reason for the problem in the head area. They wrote the main reasons for the other fields. But, some of them wrote the solutions in the bottom area. Instead of writing the reasons under the subtitle, there were those who wrote the solution suggestions there.

C1_A1_T: Sadece o hani o balık kılçığındaki problemin nedenini o baş kısma yazdılar. O diğer bölümlere ana nedenleri yazdılar. Sadece alt tarafa hani çözüm önerilerini yazanlar oldu. Hani alt başlık altında nedenlerini yazmak yerine oraya çözüm önerilerini de yazanlar oldu.

All the aforementioned *misconceptions* were expressed by only the teacher during the interview of Activity-1 (*f*=4) and Activity-2 (*f*=3) in the first cycle. Additionally, he referred to the misconceptions as one of the challenges of the activities during the interview of the first activity (*f*=2) in the second cycle, according to the findings in Table 4.23.

The findings provided in Table 4.23 also indicated that only one of the interviewed students described *the misconception* for the first activity (*f*=1) in the second cycle. This student expressed his/her misconception on science subject in this activity as in the following:

> *C2_A1_FG3_S3: Teacher, I thought we would reduce the friction force.*
>
> *C2_A1_FG3_S3: Hocam ben şey sürtünme kuvvetini azaltacağız zannediyordum.*

Low Success Level

Similarly, the *low success level* of the students was found as another challenge under the category of lack of readiness in the current study. Based on this challenge, the students who had a low success level in not only *the related courses* but also in *other courses* had difficulties during the activity process. This result indicated the importance of the other courses such as *linguistic* on the students' readiness for the activities.

The findings shown in Table 4.23 indicated that only the teacher expressed the *low success level* of students as a challenge for the activities. He mentioned this success level during only the interviews of Activity-1 (*f*=2) and Activity-4 (*f*=3) in the second cycle. According to him, the low level of students' success was a significant predictor of the troubles of the activities that students faced during the activities. He commented on this challenge as follows:

> *C2_A4_T: While expressing themselves there, some students especially in male class had problems even at the point of forming the sentences. So it is clear and obvious that these students are not good at Turkish lessons and they have weakness there.*
>
> *C2_A4_T: Oradaki kendilerini ifade ederken ki o noktada cümleye mesela çok şeydi bazı özellikle erkek sınıfındaki öğrencilerde cümle kurma noktasında dahi sıkıntılar vardı. Yani orada bu çocukların Türkçe*

derslerinin çok iyi olmadığı zayıf olduğu açık ve aşikar bir şekilde belli oluyor.

Time

The time of the activities was found as one of the challenges based on the findings of the current study. The underlying factors of this challenge were *the duration* and *the schedule* of the activities. Some of the participants agreed that the duration of the activities prevented them from solving the ill-structured problems in time. Additionally, the schedule of the activities brought several difficulties to the students. Therefore, some of them needed extra effort to overcome these troubles during the implementation process. The underlying factors of the time with the frequency distribution of the participants' descriptions were given in Table 4.24.

Table 4.24 Frequency Distribution of Codes belongs to Category of Time

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Duration	1	-	-	-	4	5 (*n*=2)	-	-
	Schedule	-	-	5	-	3	-	3	1 (*n*=1)
Cycle 2	Duration	4	2 (*n*=2)	-	-	-	1 (*n*=1)	2	1 (*n*=1)
	Schedule	-	-	-	-	-	-	6	1 (*n*=1)

**n* refers to the number of students responsible for the verbal occurrences within interviews

Duration

The findings presented in Table 4.24 indicated that *the duration* of the activities as a challenge was reported only by two students during focus group meeting of Activity-3 (*f*=5) in the first cycle. In the second activity, the students mentioned this challenge for Activity-1 (*n*=2, *f*=2) firstly. Then, one of the interviewed students reported the duration of the activities as one of the challenges during the focus group meeting of Activity-3 (*f*=1) and Activity-4 (*f*=1).

According to the students, *the duration* was one of the main barriers they faced during the activities. In fact, the students mostly complained about *the insufficient* *time* when they did not finish their work at the end of the activity. According to those students, this challenge obstructed them from creating their dreams. Therefore, they did not finish their activity as their wish. One of the students during the focus group interview commented on this as in the following:

> *C1_A3_FG1_S1: This is the top layer. As you see now, we wanted to create a new layer below but the time was not sufficient. We were going to create a colorful layer below the colorless one.*

> *C1_A3_FG1_S1: Şu anda bu üstü, altında gördüğünüz gibi altına bir kat daha yapacaktık ama zamanımız yetmedi. Bu renksiz altına bir tane daha renkli bir kat yapacaktık.*

Similarly, according to the teacher, it was challenging for the students to design the products that are exactly in their minds during the activities because of the *insufficiency of the time.* According to him, *the duration* of the activities was mostly a problem during the beginning of the implementationswhen the students were not experienced enough for the activities. He expressed this as follows:

> *C2_A1_T: The first activity took too long. It might be because the children had not done such activity before or might be because they did not fully understand it. You know, we had to extend the duration of the first activity a little.*

> *C2_A1_T: Birinci etkinlik çok uzun sürdü. Burada çocukların hani daha öncesinde böyle bir etkinlik yapmamış olmalarından dolayı ya da tam olarak belki anlamadıklarından dolayı da olabilir. Hani o etkinliği biraz uzatmak durumunda kaldık. Birinci etkinliğin süresini.*

The teacher implied the importance of the inexperience of the students on the duration of the activities. Similar to this expression, *the duration* of the activities was mentioned by the teacher during the interview of Activity-3 (*f*=4) in the first cycle. In the second cycle, he expressed this challenge for Activity-1 (*f*=4) and Activity-4 (*f*=2), according to the findings presented in Table 4.24.

Schedule

In addition to the duration of the activities, *the schedule* of them was also reported as a challenge by the participants. According to the findings in Table 4.24, one of the students expressed this challenge for Activity-4 (*f*=1) in the first cycle. This student complained about the schedule of the activities because it *coincided with Ramadan*. According to him, since they were fasting in Ramadan, it was difficult to conduct the activity properly. Similarly, another student reported this challenge for the Activity-4 (*f*=1) in the second cycle. According to this student, it was not easy to complete the activity due to the fact that it was conducted *at the end of the semester*.

The teacher also commented on the challenges regarding *the schedule* of the activities. According to the findings presented in Table 4.24, he described the schedule of the activities as one of the challenges during the interview of Activity-2 (*f*=5), Activity-3 (*f*=3), and Activity-4 (*f*=3) in the first cycle. In the second cycle, he mentioned the challenge about schedule of the activities only during the interview of last activity (*f*=6).

The activities lasted until the end of the semester in both cycles. As the students, the teacher also reported being *at the end of the semester* as a difficulty for the activities. To him, the reason for the decline of students' participation in the activities was the result of this scheduling.

> *C2_A4_T: Yes, since it is the end of the semester, the lastweeks, the students did not join in.*
>
> *C2_A4_T: Evet işte dönem sonu olduğu için son haftalar olduğu için hani öğrenciler gelmediler.*

Goal Orientation

During the activity time, the students had to focus on a goal aiming at solving the ill-structured problem presented in the activity sheet. However, several students had difficulties in this focus, and they went quickly beyond the goal of the activity. This *goal orientation* occurred in two ways: *expanding shift* and *narrowing shift*, as they were shown in Table 4.25.

Table 4.25 Frequency Distribution of Codes belongs to Category of Goal Orientation

	Codes/**Participants**	**Activity 1** T	**Activity 1** S	**Activity 2** T	**Activity 2** S	**Activity 3** T	**Activity 3** S	**Activity 4** T	**Activity 4** S
Cycle 1	Expanding shift	4	-	1	-	3	-	-	-
	Narrowing shift	-	-	-	-	4	-	-	-
Cycle 2	Expanding shift	2	-	-	1 (*n*=1)	-	1 (*n*=1)	1	-
	Narrowing shift	-	4 (*n*=3)	-	-	-	-	1	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Expanding Shift

The expanding shift of students' focus was mentioned by only the teacher in both cycles. According to him, some of the students thought the course as *gameplay* in previous years. Therefore, they usually asked to play *computer games* during their early activities. The distracting elements were not only the computer games during the activities. *The stationery materials* also had a distracting aspect for the students, and the students caught up quickly in this alluring aspect during the activity time. As a result, in both cases, the students went beyond the scope of the activities. An example of this situation was that they found a solution for non-handicapped people for Activity-3 while the problem statement asked a solution for the disabled. This was expressed by the teacher as follows:

> *C1_A3_T: The problem situation was at a level that children could understand, but as I said,though they watched the disabilities in the video, on the point of thinking only the disabled people when solving the problem, they did something for non-handicapped people, not the disabled.*

> *C1_A3_T: Problem durumu çocukların anlayabileceği seviyedeydi, düzeydeydi ama dediğim gibi...engelli olarak ve de sadece engellileri*

düşünme noktasını video da izlediler ama problem çözerken engellileri değil de normal vatandaşlara göre de yaptıkları oldu.

The findings in Table 4.25 revealed that the teacher described *the expanding shift* during the interview of Activity-1 (*f*=4) for first time in the first cycle. Then, he reported this challenge during the interview of Activity-2 (*f*=1) and Activity-3 (*f*=3). However, he did not report anything about the expanding shift for Activity-4 in this cycle. Similarly, he did not defined this shift as a challenge for Activity-2 and Activity-3 in the second cycle. By contrast, he reported them during the interviews of Activity-1 (*f*=2) and Activity-4 (*f*=1) in this cycle. One of these activities, the teacher referred to the expanding shift with *the stationery materials* during activity as in the following:

C1_A1_T: While students were coding, they put the codes into the second plan and tried to prepare the product via stationery materials. The effect of the allure of that materials was like that for the students there.

C1_A1_T: Orada kod yazarken hani, kodlamayı hani belli noktalarda hani biraz ikinci plana atıp daha çok hani o malzemelerden bir ürün ortaya çıkarmaya çalıştılar. Oradaki malzemelerin vermiş olduğu albeninin çocuklara etkisi bu şekilde oldu.

Narrowing Shift

In the second way of goal orientation, the focus of students became narrower during the activity process. The students described the reason for this shift as *the absence of the option of turning back* during the activity process. According to them, they came up with several new paths when they were going on their solution. However, the time of these discoveries was usually too late to go back and apply them. Therefore, this shift was a barrier for them to complete the activity as they wished. According to the findings related to the students provided in Table 4.25, the reason for *the narrowing shift* was expressed for only the Activity-1 (*f*=4) in the second cycle. One of the students commented on this shift as in the following:

C2_A1_FG2_S1: So it came to our mind after doing it. Then, there would be no turning back.

C2_A1_FG2_S1: Yani yaptıktan sonra aklımıza geliyor. Sonra da geri dönüşü olmuyor.

The findings in Table 4.25 indicated that the teacher reported *the narrowing shift* of goal orientation for only two activities in both cycles. In detail, he expressed this challenge during the interviews of Activity-3 (*f*=4) in the first cycle and Activity-4 (*f*=1) in the second cycle. According to him, the students narrowed their goals by *focusing on a specific solution*. The activity process was usually affected by this shift negatively since the students could not see other solution paths of the ill-structured problem. He expressed this as in the following:

C1_A3_T: …the subject has a very broad set of solutions, but the students have directed to a certain natural disaster and a disability group.

C1_A3_T: …çok geniş bir çözüm kümesi olan bir konu ama öğrenciler hep belli bir doğal afeti ve belli bir engel grubuna yönlendiler.

Lack of Motivation

The findings of the current study revealed that *the lack of students' motivation* was another challenge of the activities. The factors resulting as the low level of motivation were *emotional routers, unwillingness on duty*, and *the lack of video,* based on the findings provided in Table 4.26.

Table 4.26 Frequency Distribution of Codes belongs to Category of Motivation

	Codes/**Participants**	**Activity 1** T	**Activity 1** S	**Activity 2** T	**Activity 2** S	**Activity 3** T	**Activity 3** S	**Activity 4** T	**Activity 4** S
Cycle 1	Emotional routers	-	-	-	-	-	2 (*n*=2)	-	-
	Unwillingness in duty	-	1 (*n*=1)	-	1 (*n*=1)	-	-	-	-
	Lack of video	-	-	-	-	-	-	-	-
Cycle 2	Emotional routers	-	-	-	3 (*n*=2)	-	4 (*n*=3)	-	-
	Unwillingness in duty	1	-	-	-	-	1 (*n*=1)	-	-
	Lack of video	-	-	-	-	-	-	2	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Emotional Routers

One aspect of the instructional challenges for the motivation of students was *emotional routers.* In fact, the motivation of students usually decreased during the activity process when there were emotional routers. These emotional routers were mainly about *the scenario of the activity* or *the content of the video*. According to the findings provided in Table 4.26, only the students reported these routers. In detail, two students described these emotional routers as a source of low motivation in the first cycle. The challenge was described during the focus group meeting of Activity-3 (*f*=2) in this cycle. In the second cycle, two students described them as a challenge during the interview of Activity-2 (*f*=3) firstly. Then, three interviewed students reported emotional routers as one of the instructional challenges of the activities during the focus group meeting conducted after the third activity (*f*=4) last time.

The interviewed students after the second activity expressed that they felt unhappy because they thought that *people would not use the solution* they found during the activity. Other emotional routers were expressed by the students who were interviewed after the third activity. They commented that they felt unhappy about *watching a video* that was about disabled people. Some of them also complained about *the scenario of the activity,* which contained natural disasters and disabled people. According to them, talking about the people with disabilities experienced difficulties in natural disasters was upsetting for them. One of the students commented on this as in the following:

> *C1_A3_FG3_S1: Talking about the hearing and visually impaired people is the negative side. This could be something. We were sorry about it.*

> *C1_A3_FG3_S1: Olumsuz yönü işitme ve görme engelliler yani onların hakkında konuştuk. Bu şey olabilir. Üzüldük.*

Unwillingness in Duty

In some cases, the lack of motivation in activities emerged as an *unwillingness in duty*. According to the findings presented in Table 4.26, this unwillingness expressed by only one of the interviewed students during the interviews of Activity-1 (*f*=1) and Activity-2 (*f*=1) in the first cycle. In the second cycle, again only one student reported this challenge during the focus group meeting of Activity-3 (*f*=1). According to these students, the duty determined via division of labor within the group was interrupted in some cases since some of them did not want to do that work. One of the students expressed the *unwillingness in programming* the robot as follows:

> *C1_A1_FG1_S3: None of us wanted to program the robot.*

> *C1_A1_FG1_S3: Hiçbirimiz robotu programlamak istemiyorduk.*

The teacher also commented on this unwillingness as a challenge during the interview of Activity-1 (*f*=1) in the second cycle. He expressed the unwillingness of students to *fill the activity sheet* and its effect on the activity process as in the following:

> *C2_A1_T: …being unwilling to fill the activity sheet completely emerged as a negative situation for us.*

> *C2_A1_T: …etkinlik kağıdını tam olarak dolduramamaları o konuda isteksiz olmaları olumsuz bir durum olarak bizim karşımıza çıktı.*

Lack of Video

The lack of the video, another factor of the low level of motivation, was expressed by only the teacher. He commented on this for only the Activity-4 (*f*=2) in the second cycle based on the findings in Table 4.26. According to him, the attention of students was not drawn since the video was not used in this activity. Therefore, the students had difficulties in understanding the problem clearly. This challenge was expressed by the teacher as follows:

> *C2_A4_T: The reason for the pendency of the event in the fourth activity might be related to the absence of the video.*

> *C2_A4_T: Dördüncü etkinlikte olayın biraz havada kalması o etkinlikte videonun olmaması ile ilgili olabilir.*

External Challenges

The remaining instructional challenges of the activities were categorized as *external challenges* which were all about the *administrative issues*, *living conditions* and *the readiness of the teacher*. According to the data provided in Table 4.27, only the teacher mentioned these challenges.

Table 4.27 Frequency Distribution of Codes belongs to Category of External Challenges

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Administrative challenges	-	-	-	-	-	-	-	-
	Not being with family	-	-	-	-	-	-	-	-
	Readiness of teacher	-	-	-	-	1	-	-	-
Cycle 2	Administrative challenges	6	-	-	-	-	-	2	-
	Not being with family	1	-	-	-	-	-	3	-
	Readiness of teacher	2	-	-	-	-	-	-	-

Administrative Challenges

The administrative tasks for the teacher in the second cycle were among the external administrative challenges. The teacher had to leave the activity and go to those tasks during the implementation. Therefore, these tasks were a significant obstacle to the activity process. Additionally, in the same cycle, there was a *compulsory student exchange* between the classes that was pushed by the administration of the school. This exchange affected the activity process negatively.

These external administrative challenges were expressed by the teacher for only Activity-1 (f=6) and Activity-4 (f=2) in the second cycle, based on the data provided in Table 4.27. He expressed one of these challenges as the following:

> *C2_A4_T: In addition, the exchange of students in the male group caused recreating the groups. In other words, our course may be negatively affected due to a situation outside the classroom where we cannot be involved.*
>
> *C2_A4_T: Bir de erkek grubunda öğrenci değişiminin olmuş olması bizim işimizi tekrar grupların oluşturulmasına neden oldu. Yani sınıf dışındaki bizim dahil olamadığımız müdahil olamadığımız bir durumdan dolayı dersimiz olumsuz bir şekilde etkilenmiş olabilir.*

Not Being with Family

Not being with family was a specific condition for the second cycle of the study. Several students in this cycle had to *stay at dormitories* since they were away from their homes. This challenge was encountered during all activities. However, the teacher expressed not being with family as a challenge during only the interviews of Activity-1 (f=1) and Activity-4 (f=3), based on the data presented in Table 4.27. According to him, the students who stayed at the dormitory could not participate in the activities as ready. He expressed this as follows:

C2_A4_T: That some students do not have a regular sleep time since they stay in dormitories, different dormitories, not at home, not with their families.

C2_A4_T: Bazı öğrencilerin hani yurtta kalması yani evde değil de aileleriyle değil de işte farklı yurtlarda kalmalarından dolayı bir uyku saatinin olmaması.

Readiness of Teacher

The readiness of the teacher was also one of the external challenges of the activities. According to the findings provided in Table 4.27, *the temporary health problems* affected the readiness of the teacher for the activities. The teacher expressed these health problems as a readiness challenge for only Activity-1 (*f*=2) in the second cycle. Additionally, the teacher was not feeling *sufficient for design*. He expressed this was a readiness problem, too. Consequently, he reported that he could not help students with their designs during Activity-3 (*f*=1) in the first cycle. He commented on this as in the following:

C1_A3_T: In the design phase, my skill is very limited so I can not even do most of the things that students do in design such as the bonding cardboard that way and so on.

C1_A3_T: Tasarım bölümünde hem kendi becerim çok sınırlı düzeyde hatta çocukların tasarım boyutunda yaptıkları şeylerin çoğunu ben yapamayabilirim yani. O şekilde karton birleştirmedir, şeydir hani.

Logistic Challenges

The results of the data analysis of the current study indicated that *the logistic challenges* were the second theme of the challenges of the activities. This theme was constituted by two categories: *resource problems* and *learning environment.* The theme and the related categories were presented in Figure 4-9.

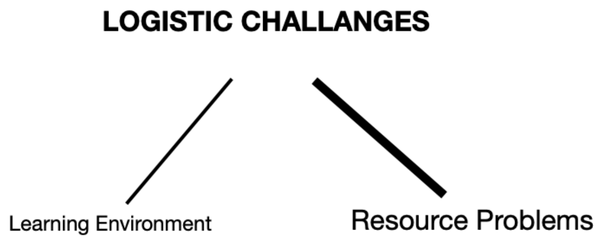

Figure 4-9 Categories of Logistic Challenges Theme

The data sources for these categories were the interviews with the teacher and the students in both cycles of the implementation. A code tree including categories of both categories and the related codes for each category listed from most cited to the least was presented in Table 4.28. The categories and the related codes of them were elaborated one by one under this presentation.

Table 4.28 The Code Tree of Logistic Challenges Theme

Categories/Codes	Σf
Resource Problems	**90**
Problems of stationery materials	42
Robotic problems	39
Infrastructural problems	9
Learning Environment	**44**
Noise	29
Classroom structure	7
Classroom size	6
Violation of rules	2

Resource Problems

There were several types of resources that the students utilized to solve the given ill-structured problem during the activities. The students often faced several problems with these resources. The majority of these problems were mainly about *stationery materials* and *robots*. Additionally, some *infrastructural problems* also appeared during the process. All of these problems were reported as one of the challenges of activities by the participants. The frequency distribution of the participants' descriptions on the problems about these resources were provided in Table 4.29.

Table 4.29 Frequency Distribution of Codes belongs to Category of Resource Problems

	Codes/**Participants**	**Activity 1** T	**Activity 1** S	**Activity 2** T	**Activity 2** S	**Activity 3** T	**Activity 3** S	**Activity 4** T	**Activity 4** S
Cycle 1	Problems of stationery materials	1	8 (*n*=3)	-	2 (*n*=1)	2	8 (*n*=3)	-	2 (*n*=2)
	Robotic problems	11	10 (*n*=3)	-	-	1	4 (*n*=2)	-	-
	Infrastructural problems	-	-	-	-	-	-	-	-
Cycle 2	Problems of stationery materials	1	5 (*n*=4)	-	10 (*n*=6)	-	-	1	2 (*n*=2)
	Robotic problems	-	2 (*n*=2)	-	7 (*n*=4)	-	4 (*n*=4)	-	-
	Infrastructural problems	5	-	2	-	-	-	2	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Problems of Stationery Materials

The distribution of stationery materials was one of the problematic situations during the activities, according to both students and the teacher. Especially for the first activities of the implementation in the first cycle, these materials were given to the students *randomly*. For this activity, a great deal of chaos was observed by the researcher during the distribution of them. It was also obvious that some students envied these products from others in several activities, so they took various ways to own them. Additionally, some of these materials were *not suitable for the age group* of the students. Therefore, these specific materials such as a razor blade knife could not be used by the students. The teacher and the researcher used these materials instead of the students during the activities. All of these problems with the resource of *stationery materials* was one of the challenges of the activities, according to the participants.

According to the findings related to participants in Table 4.29, *problems about the stationery materials* as a challenge for the activities were reported by all interviewed students during the focus group meeting of Activity-1 (*f*=8) at the beginning of the first cycle. Next week, these problems were mentioned by only one of the interviewed students (*f*=2). Then, three interviewed students reported these problems during the focus group meeting of the third activity (*f*=8). During the last interviews, two of the students mentioned these problems again in this cycle (*f*=2). In the second cycle, the students did not report any of the problems with stationery materials for Activity-3. However, six students described most of these problems with the stationery materials for Activity-2 (*f*=10) in this cycle. Similarly, four students during Activity-1 (*f*=5) and two students in Activity-4 (*f*=2) described the problems of stationery materials as one of the challenge of the activities in this cycle. In addition to these interviews, these problems were also reported on the reflection papers in this cycle. For instance, one of the students referred to the distribution problem of these materials on the reflection paper of the first activity as in the following:

> *C2_A1_R_S7: Some of our friends have stored things that they want to use somewhere beforehand.*
>
> *C2_A1_R_S7: Bazı arkadaşlarımız kullanacakları eşyaları daha önceden bir yerlere sakladılar.*

The teacher also expressed *the problems of stationery materials* as a challenge for the activities. He described these problems for Activity-1 (*f*=1) at the beginning of the implementation and repeated them during the interview of Activity-3 (*f*=2) in the first cycle. Similarly, his descriptions concerning the problematic issues about the stationery materials belonged to the interviews of Activity-1 (*f*=1) and Activity-4 (*f*=1) in the second cycle, as demonstrated by the data presented in Table 4.29. One of those descriptions was about stationery materials that were not suitable for children's ages as follows:

> *C1_A3_T: During the design, the materials that children could use in that age group is more limited, the time is already limited, and the materials they can use is also limited. For instance, they did not use such materials as utility knife, nails, and hammer, which were sharp objects.*
>
> *C1_A3_T: Tasarım sırasıda hani malzemeler hani çocukların o yaş grubunda kullanabileceği malzemeler daha sınırlı, zaman zaten sınırlı,*

kullanabileceği malzemeler sınırlı örneğin maket bıçağının kullanımında hani kesici aletler ya da çivi gibi, çekiç gibi şeyler hani kullanmadılar.

Robotic problems

The findings in Table 4.29 indicated that another problem encountered during the activities about the resources was related to *robots* and *their pieces*. This problem was expressed by all the interviewed students for Activity-1 (*f*=10) at the beginning of the implementation. Then, other two students expressed the problems about the robots during the focus group meeting of Activity-3 (*f*=4) in this cycle. In contrast, the students did not mention the problem with robots during the interview of second and forth activity in this cycle. Likewise, they did not describe the problems about robots and their pieces as a challenge for Activity-4 in the second cycle. In contrast, two students described the robotic problems during the interview of the first activity. Similarly, four students who participated in the focus group meeting expressed this kind of problems after the second activity (*f*=7). Other four interviewed students also reported the problems about the robots and their pieces during the focus group meeting of Activity-3 (*f*=4) in this cycle.

In their descriptions, the students mostly underlined the problem of *the durability of robot kits*. *Breakdown of the robots' pieces* during the activity was an important challenge, according to them. One of the students expressed the problem with the wheels of robots as in the following:

> *C2_A3_FG4_S2: A wheel came out of its place and then we put it back in. The other wheel, the left one, didn't fit its place.*

> *C2_A3_FG4_S2: Bir de bir tekerlek çıktı onu tekrar taktık. Öbürü de tam girmedi şu sol teker.*

In addition to the breakdown of robots, the teacher also commented on the *insufficiency of the robotic kits* as a challenge for the activities. His descriptions on the issues of insufficiency and durability of the robotic kits were quite high for Activity-1 (*f*=11) at the beginning of the first cycle. Then, he expressed one of these issues during the interview of the third activity one more time in this cycle. On the contrary, he did not mention these problems for Activity-2 and Activity-4 in this cycle as well as all activities in the second cycle. In one of his descriptions, he put forward that these problems restricted students from developing alternative solutions by saying the following:

> *C1_A3_T: The parts of the robot are not exactly enough. There are limited number of sensors.*
>
> *C1_A1_T: Ya da robotun parçaları tam olarak yeterli değil. Algılayıcılar hani sınırlı sayıda.*

Infrastructural Problems

According to the findings provided in Table 4.29, only the teacher reported the *infrastructural problems* as a challenge for the activities. In detail, he did not specified any infrastructural problem for the activities in the first cycle. On the other hand, he described these problems as a challenge for almost all activities in the second cycle. The frequency of his descriptions on these problems was quite high for Activity-1 (*f*=5). In contrast, he described these problems for Activity-2 (*f*=2), and Activity-4 (*f*=2) with a lower frequency.

According to the teacher, these *infrastructural problems* of the laboratory caused several *technical challenges* such as *connection problems* of robots to the computers during the activities. The teacher expressed this challenge as in the following:

> *C2_A4_T: Another negative situation is that we had technical difficulties. Just as the computer didn't recognize the cards, it caused a prolongation of our time at the first activity and caused the reduce of efficiency.*
>
> *C2_A4_T: Diğer bir olumsuz durum teknik sıkıntılar yaşanmıştı. İşte bilgisayarın kartları tanımaması gibi o da bizim ilk etkinlikte süremizin uzamasına neden oldu ve verimin düşmesine neden oldu.*

Learning Environment

The findings of the current study revealed that the last category of *logistic challenges* was all about the *learning environment*. Among these challenges, *the noise* was one of the crucial environmental problems during the activities. The majority of the participants expressed that they were negatively affected by the noise during the activity. Additionally, the participants reported several issues about *the classroom structure*, *the classroom size*, and *the violation of rules* as the source of learning environment challenges. The frequency distribution of the participants' descriptions concerning these sources of the challenges was given in Table 4.30.

Table 4.30 Frequency Distribution of Codes belongs to Category of Learning Environment

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Noise	2	8 (*n*=3)	-	4 (*n*=2)	-	1 (*n*=1)	-	-
	Classroom structure	-	-	-	-	-	-	-	-
	Classroom size	-	-	-	-	-	-	-	-
	Violation of rules	-	-	-	-	-	-	-	-
Cycle 2	Noise	1	2 (*n*=2)	-	2 (*n*=2)	-	6 (*n*=6)	2	1 (*n*=1)
	Classroom structure	5	-	-	-	-	1 (*n*=1)	1	-
	Classroom size	3	-	-	-	-	-	3	-
	Violation of rules	-	-	-	-	-	1 (*n*=1)	1	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Noise

The noise problem was an expected barrier for a group work environment. However, despite several precautions such as warnings on it, this problem could not be prevented during the activities in the current study. Therefore, it was reported as a challenge for the activities several times by the participants. In detail, the data provided in Table 4.30 indicated that the noise problem was firstly described by all the interviewed students during the focus group meeting of Activity-1 (*f*=8) at the beginning of the implementation. Then, two students reported it in the following week again (*f*=4). Lastly, this challenge was described by one of the students during the focus group meeting of the third activity in this cycle. In the second cycle, the descriptions concerning the noise as a challenge was highlighted during the focus group meeting of Activity-1 by two students, firstly. Then, it was again reported by another two interviewed students for Activity-2 (*f*=2). For the next activity, totally six interviewed students described the noise problem as a barrier for the activities again (*f*=6). Lastly, one of the students described this challenge during the focus group meeting of Activity-4 (*f*=1) in this cycle.

The students expressed *the noise* as a challenge for the activities since it prevented them from working comfortably during the activity process. According to them, one of the sources of the noise during the activities was *the buzzer of the robot*. Additionally, several students thought that some of their friends in other groups could *be over talker* while they were working. Therefore, they were not able to hear their group mates. One of the students commented on this as such:

> *C2_A3_FG3_S1: Everyone's speech. For example, my teacher, we had something to do, but I forgot about it, we all forgot. We were going to do something, but our other friends distracted us. Therefore, we couldn't do it.*
>
> *C2_A3_FG3_S1: Herkesin konuşması. Mesela hocam bizim şu an yapacağımız bir şey vardı ben onu unuttum hepimiz unuttuk aslında. Bir şey yapacaktık ama öbür arkadaşlarımız bizim kafamızı dağıttı biz yapamadık.*

The teacher commented on *the noise* as a challenge only during the interview of Activity-1 (*f*=2) in the first cycle. In the second cycle, he described this challenge for Activity-1 (*f*=1) and Activity-4 (*f*=2). According to him, the students did not work collaboratively on such activities before the implementation process of both cycles. Therefore, the students faced this challenge, especially *for the early activities*. However, it was an important barrier to these activities. He expressed the noise as a challenge during the interview of the first activity by saying the following:

C1_A1_T: We can evaluate the abundancy of noise and the increase in voice levels during the interaction of students at work as a negative situation.

C1_A1_T: Sesin çok fazla olması, öğrencilerin etkileşimi sırasında işte seslerinin çoğalması, artması olumsuz bir durum olarak değerlendirebiliriz.

The teacher had to warn the students during the activities to eliminate this problem. One of the students drew the classroom in her drawing (Figure 4-10) and portrayed the teacher while "warning the students to silence them" in the supported text.

C2_A1_D_S3:

Figure 4-10 Drawing of S3

Classroom Structure

The classroom structure was one of the specific challenges of the second cycle of the study. In detail, the participants reported that *the layout* of the IT laboratory was *inappropriate for the group work* in this cycle. According to the findings represented in Table 4.30, the problems with the classroom structure were pointed out by the teacher during the interviews of Activity-1 (*f*=5) and Activity-4 (*f*=1). The findings also revealed that only one of the students expressed that the structure of the classroom had *uncomfortable conditions* for them during the focus group interviews of Activity-3 (*f*=1). This student and the teacher commented on the unsuitable classroom structure as follows:

> *C2_A3_FG1_S3: Our back hurts because there is no back of the chairs.*
>
> *C2_A3_FG1_S3: Sandalyelerin arkası olmadığı için belimiz ağrıyor.*
>
> *C2_A1_T: The location of the laboratory and the seating arrangement are important. They could not communicate fully with each other, especially when filling in the activity sheet.*
>
> *C2_A1_T: Laboratuvarın bulunduğu konum da önemli, sıra düzeni önemli. Özellikle etkinlik kağıdını doldururken tam olarak birbirleriyle iletişim kuramadılar.*

Classroom Size

Another specific challenge for the second cycle was *the classroom size*, according to the findings shown in Table 4.30. Since the study conducted with different two classrooms in this cycle, the teacher had the opportunity to compare the classroom size for different groups in this cycle. He expressed this challenge during the interview of Activity-1 (*f*=3) and Activity-4 (*f*=3). According to him, *the number of students* in one of the classes was *very high* so that the students in that classroom had several problems during the activity time. He commented on this as in the following:

> *C2_A4_T: The case that the number of students in the classroom was slightly higher in boys caused negativity.*
>
> *C2_A4_T: Sınıftaki öğrenci sayısının erkeklerde biraz daha fazla olması olumsuzluğa sebep oldu.*

Violation of Rules

The activity rules were set by the teacher and the researcher after the first cycle of the study. These rules were derived from the results of this cycle and typed on a paper before the first activity of the second cycle (please see Appendix N). The teacher explained these rules one by one to the students at the beginning of the first activity in the second cycle. Additionally, he added that they were free to set new rules for their own groups.

The violation of these activity rules was a learning environment challenge, according to one of the students and the teacher. The teacher compared the classrooms that separated based on the gender of students during the interview of Activity-4 (*f*=1). During this interview, he explained that *the boys did violate* the activity rules more than the girls. Therefore, it was an important challenge for the classroom composed of boys during the activity process. Similarly, only one student in this classroom referred to this challenge as a negative situation during the focus group meeting of Activity-3 (*f*=1), according to the findings displayed in Table 4.30. This student commented on the challenge as in the following:

> *C2_A3_S2: Badly, my friends on the team didn't follow the rules.*
>
> *C2_A3_S2: Kötü olarak ekipteki arkadaşlarım kurallara uymuyordu.*

4.5 Characteristics of problem-solving activities designed for middle school students to solve ill-structured problems in science with educational robots (RQ2)

The second sub-question of the study was about the characteristics of the activities in which middle school students solved ill-structured science problems by using educational robots. The researcher collected the data from the participants in order to unveil these characteristics throughout the implementation of the activities in two cycles. The primary data sources were the interviews with the teacher and the students during these cycles. The reflection paper, text supported drawings of students, and their activity sheets were also utilized as supportive data sources to develop and organize the themes, categories, and codes of the findings. Additional data from the researcher's observations and test scores (collected from an academic achievement test on science and unplugged algorithm quiz) were also employed to support the findings concerning the characteristics of the activities. In general, it was deduced from the analysis of the data that there were three characteristics of the activities called *structural characteristics*, *instructional features*, and *contributions*.

Structural Characteristics

The baseline of the activities was predicated on ill-structured problems. Therefore, several specific *structural characteristics* emerged after the data analysis of the current study. According to the findings of this analysis, the activities' structural characteristics were explicitly categorized as *complexity, equipment, structure level, dynamicity,* and *domain.* The theme and the related categories were presented in Figure 4-11.

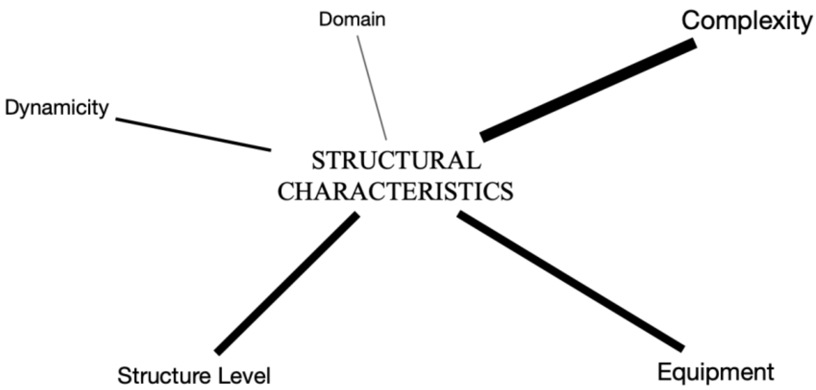

Figure 4-11 Categories of Structural Characteristics

The main data sources for the emerged categories were the interviews with the teacher and the students in both cycles of the implementation. A code tree including these categories and the related codes listed from the most cited to the least was displayed in Table 4.31. The codes and categories were elaborated one by one below.

Table 4.31 The Code Tree of Structural Characteristics Theme

Categories/Codes	Σf
Complexity	**105**
Complexity indicators	92
Simplicity indicators	13
Equipment	**102**
Stationery materials	58
Robotic materials	41
Auxiliary materials	3
Structure Level	**74**
Unifying factors	40
Diversifiers	34
Dynamicity	**48**
Dynamicity boosters	33
Dynamicity reducers	15
Domain	**44**
Related fields	30
Daily life context	14

Complexity

Based on the findings of the study, *the complexity* of the activities was found as a twofold structural characteristic of the activities. In one of them, the activities hosted several factors that increased the difficulty level of the activities for the students. These *complexity indicators* were mostly the states that the students had to manage throughout the problem-solving process, and they tended to need extra effort to continue the activity process. In contrast, *the simplicity indicators,* which worked in the opposite direction of the complexity factors, made the activities easier for students. The participants of the study reported these indicators several times during the data collection process. The frequency of distribution of the participants' descriptions concerning both indicators was provided in Table 4.32.

Table 4.32 Frequency Distribution of Codes belongs to Category of Complexity

	Codes/**Participants**	**Activity 1**		**Activity 2**		**Activity 3**		**Activity 4**	
		T	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Complexity indicators	1	11 (*n*=3)	-	11 (*n*=4)	2	11 (*n*=4)	-	5 (*n*=2)
	Simplicity indicators	2	3 (*n*=3)	2	-	1	-	-	-
Cycle 2	Complexity indicators	3	14 (*n*=7)	-	13 (*n*=5)	-	14 (*n*=7)	2	5 (*n*=3)
	Simplicity indicators	-	1 (*n*=1)	-	3 (*n*=2)	-	1 (*n*=1)	-	-

*n *refers to the number of students responsible for the verbal occurrences within interviews*

Complexity Indicators

The findings in Table 4.32 disclosed that the students described *the complexity indicators* of the activities with a higher frequency during the data collection process. In detail, the interviewed three students pointed out the complexity indicators firstly during the interview of Activity-1 (*f*=11) at the beginning of the first cycle. The descriptions of the students on those indicators continued with the same frequency throughout the following two weeks (Activity-2, Activity-3, *f*=11). Additionally, two students in the group meeting of the last activity (*f*=5) mentioned the indicators last time in this cycle. Similarly, seven interviewed students described the complexity indicators for Activity-1 (*f*=14) at the beginning of the second cycle. In the following two activities, the descriptions of the students were as pretty high as the first one. In fact, five interviewed students described these indicators during the focus group meeting conducted after second activity (*f*=13) while seven students during the interview of the third activity (*f*=14). For the last activity, three students referred to the complexity indicators (*f*=5) during the group meeting at the end of the implementation.

According to the descriptions of the students, *the perceived difficulty* and *encountered troubles* during the problem-solving process were *the complexity indicators* of the activities. In detail, *the phases of the activities* were perceived as difficult by some students. Specifically, *the design, programming,* and *filling the activity sheet phases* required more effort one by one to pass the other parts for those students. In addition, some of the students commented on *the overall activity* as difficult, regardless of its parts. This perceived difficulty, albeit a whole or a piece, came up with the result that the activities took extra time to finish properly. The completion of the activities in time was also based on *encountered troubles* during the problem-solving process. In some cases, the students could not be successful because of these troubles mainly concerning *the robot pieces*, *the design of materials*, and *the activity sheets.* One of the students described encountered trouble on the connection cable of the robot in the activity as a cause of time loss. This student expressed the difficulty in uploading the algorithm in computer to the robot as one of the complexity indicators as follows:

> *C1_A2_FG1_S1: I guess there was something wrong with the computer or the cable. This cable was not uploading the program. It was said that the device was loaded successfully but it was not working on our robot.*

> *C1_A2_FG1_S1: Bilgisayarda bir hata vardı herhalde veya kabloda. Bu kablo yüklemiyordu. Cihaza başarılı yüklendi diyordu ama robotumuzda çalışmıyordu.*

Another student commented on the difficulty of *drawing an object* as *encountered trouble* during the design phase. The student expressed this complexity indicator while writing the reflection paper on the second activity in the second cycle as follows:

> *C2_A2_R_S1: There were times when I had hard time. I couldn't draw coconut.*

> *C2_A2_R_S1: Zorlandığım zamanlar oldu. Hindistan cevizi çizemedim.*

In addition to the students' explainations, the teacher also mentioned the complexity indicators during the interviews conducted after each activity. According to the findings presented in Table 4.32, he described *the troubles on the robots* and *the activity sheet* as complexity indicators. He reported these indicators during the interviews of Activity-1 (*f*=1) and Activity-3 (*f*=2) in the first cycle. Similarly, he expressed *the difficulty of overall activity*, which resulted in a failure to complete the activity properly, as complexity indicators for Activity-1 (*f*=3) and Activity-4 (*f*=2) in the second cycle.

According to the details of these findings, the students found the activities difficult because of *their sequence*. Precisely, the first activities in both cycles were thought of highly complex. Additionally, *the variety of solutions* of the third activity made it quite difficult. *The troubles* in the activities also affected the development of the product at the end of the activity. The teacher commented on one these troubles which was one of the reasons for not being able to develop a product at the end of the activity, saying the following:

> C2_A1_T: *Yes, some groups, for example, my students who wrote something completely different (on the activity sheet) could not reach at a conclusion, so there was no product.*
>
> C2_A1_T*: Evet bazı gruplar mesela bahsettiğim bambaşka bir şey yazan öğrencilerim bir sonuç çıkartamadılar yani bir ürün ortaya koyma durumu olmadı.*

As it was indicated above, the teacher implied the importance of the *activities' initial phases* for the development of a product. Finishing the activities by creating a product on time was one of the evident indicators of the students' success. Therefore, *the complexity indicators* were considered quite effective over *the success of the students* on the activities. In contrast to these indicators, *the simplicity indicators* also constituted a significant part of this success. These indicators were found as the participants' the perception of the difficulty level of the activities. Their opinion on the easiness of the activities was reported several times during the data collection process.

Simplicity Indicators

According to the findings provided in Table 4.32, both the students and the teacher described *the simplicity indicators*. Among them, the activities were getting easy in the process, according to *perceived simplicity* that was reported by three students during the focus group meeting placed after Activity-1 (*f*=3) in the first cycle. According to them, they had difficulties at the beginning of this first activity, but it became more manageable for these students throughout the problem-solving process. The other students did not mention these indicators in the remaining weeks of the implementation in this cycle. In the second cycle, one of the students described the difficulty level as easy for Activity-1 (*f*=1), and the other student explained this easiness by comparing the activities during the interview of Activity-3 (*f*=1). For the second activity in this cycle, three students agreed that the activities were getting easier throughout the implementation process (*f*=3). One of these students expressed this state of gradually getting easier with *inexperience reduction* and *getting used to the activities* as follows:

> *C2_A2_FG3_S2: For example, we were novices when the first robots came to us. We did the wrong coding; we apparently coded it wrong many times. However, now we beat our excitement, and I think our inexperience is over.*
>
> *C2_A2_FG3_S2: Mesela ilk robotlar bize geldiğinde acemiydik. Yanlış kodlama yaptık baya yanlış kodlama yaptık. Çok heyecanlıydık ama şu anda heyecanımızı yendik ve acemiliğimiz de bitti gibi düşünüyorum ben.*

In a different way from what the students claimed, the teacher reported the appropriate level of ill-structured problems in the activities as *the simplicity indicator*. He mentioned *the level of the problem* as an indicator of the simplicity of that activity during the interview of Activity-1 (*f*=2), Activity-2 (*f*=2) and Activity-3 (*f*=1) in the first cycle. For the remaining activity in this cycle and all the activities in the second cycle, he did not referred to the appropriateness of the problem level again. In previous activities, he expressed the level of the problem of the activity was proper for the students' level. Therefore, they did not experience any difficulty during the activity time. One of his comments on this issue was as in the following:

> *C1_A1_T: I think it was at a level that children can understand easily . There were no students who said that they did not understand the problem*

in their feedback in any case.

C1_A1_T: Zorluk düzeyi olarak çocukların anlayabileceği düzeyde olduğunu düşünüyorum. Zaten çocuklardan gelen dönütlerde hani, problemi anlamadık diyen hiçbir öğrenci yoktu.

Equipment of Activities

Regardless of the level of difficulty, all students tried to solve the problem and develop a product for each activity during the implementation process. In this solution and production process, students needed various *equipment* consisted of unique materials for the activities. Therefore, these materials appeared as one of the characteristics of the activities. According to the findings of the current study, the activities' equipment was categorized under three main headings: *stationery, robotic,* and *auxiliary materials*, displayed on the data provided in Table 4.33.

Table 4.33 Frequency Distribution of Codes belongs to Category of Equipment of Activities

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Stationery	6	8 (*n*=4)	5	7 (*n*=5)	3	6 (*n*=3)	2	-
	Robotic	-	1 (*n*=1)	-	5 (*n*=4)	3	8 (*n*=4)	-	3 (*n*=1)
	Auxiliary	1	-	-	-	-	1 (*n*=1)	-	-
Cycle 2	Stationery	-	13 (*n*=6)	-	3 (*n*=2)	-	5 (*n*=2)	-	-
	Robotic	-	7 (*n*=6)	-	5 (*n*=4)	-	7 (*n*=7)	-	2 (*n*=1)
	Auxiliary	-	-	-	-	-	1 (*n*=1)	-	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Stationery Materials

The stationery materials were provided for the students in their designs. Most of these materials used in the production phase were remembered by the participants during the data collection process, but the whole list based on the receipts is given in Appendix Q. According to the data gathered from the participants, the activities' stationery materials were classified as *essential*, *operational*, and *complementary*. The essential stationery materials were necessary materials utilized by almost all the groups, and they constituted an important part of the designed products. According to the reports from the participants, some of these essential stationery materials were *cardboard*, *colored papers,* and *the felt*. Additionally, the operational stationery materials were the equipment of the activities as necessary as essential stationery materials. However, these materials were mostly used for working on the essential and complementary stationery materials. Materials such as *glue*, *scissors*, and *paint* were some of the operational equipment of the activities. The last stationery materials, complementary materials, were ready-made products that helped the students' design to become better and create the simulation of the problem situation. Some of these materials were specified as the *flashlight*, *the latch*, and *the boxes* by the participants.

All these materials were touched upon mostly by the students during the data collection process. The students expressed both the name of *the stationery materials* and the purpose of their usage during the activity process. According to the findings in Table 4.33, four students mentioned these stationery materials during the interviews of Activity-1 (*f*=8) firstly. Then, all the interviewed students after Activity-2 *(f*=7) and three interviewed students for Activity-3 (*f*=6) expressed these materials again in the first cycle. In the second cycle, the majority of the students' descriptions belonged to six students, with whom the researcher interviewed after Activity-1 (*f*=13). Two interviewed students among the participants of the focus group of Activity-2 (*f*=3) and Activity-3 (*f*=5) referred to these materials with almost a close frequency.

The frequency distribution of students’ expressions in terms of types of stationery materials indicated that the they expressed mostly the essential (*f*=17) and operational (*f*=15) materials during the focus group meetings. In contrast, the complementary materials were not reported at the same rate (*f*=10). One of the students, who expressed only the operational and the essential stationery materials during the interview, commented on needed materials as follows:

C1_A1_FG1_S2: Tape, felt-tip pen, crayon, we needed them. We needed double-sided tape. We needed cardboard.

C1_A1_FG1_S2: Bant, keçeli kalem, pastel boya, onlara ihtiyacımız oldu. Çift taraflı bant ihtiyacımız oldu. Kartona ihtiyacımız oldu.

A unique part of the activity sheet also was utilized to investigate the needed materials during the activity time. Although the information requested in this field was not limited only to the stationery materials, it was revealed that many of the groups mentioned only these materials while filling this part of the sheet. One of these groups in the second cycle filled this part, as seen in Figure 4-12. In this figure, the group members expressed the needed equipment as “the wheel, and straight and lighted area. Then we have to produce a way for them with stationery materials”.

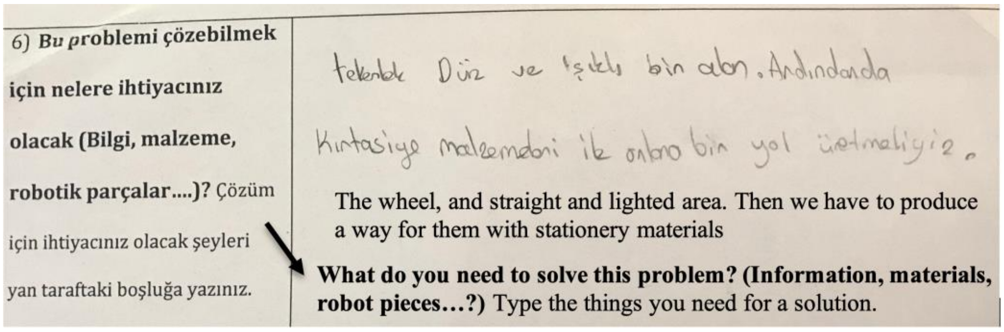

Figure 4-12 The part of Activity Sheet for Needs

The students also described the purpose of these needed stationery materials during the interviews. According to the findings concerning the purpose of *the stationary materials*, the groups mostly utilized these materials *in their designs* in which they tried to *find a solution* to the activity problem and *develop a product* with the help of these stationery materials. Additionally, they *simulated the problem statement* with these materials in some cases. One of the students expressed this purpose during the focus group interview as in the following:

C2_A1_FG2_S2: We used felt. We used silvery cardboard to evoke the water.

C2_A1_FG2_S2: Keçe kullandık. Suyu anımsatması için de simli karton kullandık.

Another purpose of *the stationery materials* was explicitly expressed by the teacher. According to his descriptions, the stationery materials given to the students during the activities *motivated* them since they were very attractive. In fact, he commented on this purpose two times during only the interview of Activity-1 in the first cycle. One of these comments was as follows:

C1_A1_T: But besides that, the fact that they produced a complete product with those stationery materials motivated the children more. They asked whether they would use these materials again in the next lesson? I received feedback to use it again.

C1_A1_T: Ama bunun yanında bir de o yardımcı malzemelerle hani tamamıyla bir ürün ortaya koymaları çocukları tabi daha fazla motive etti, hatta hani bu malzemleri tekrar bir sonraki derste kullancakmıyız? Yine kullanalım şeklinde hani geri dönütler aldık, yani aldım.

When the expressions of the teacher concerning *the stationery materials* were investigated in Table 4.33, it was seen that he expressed the name and purpose of these materials only during the first cycle of the implementation. In detail, the majority of his descriptions belonged to the interview of Activity-1 (*f*=6) at the beginning of this cycle. However, this cycle resulted in lower frequencies of the teacher’s explanations regarding the used stationery materials in the activities. The rate of his descriptions showed a gradual decline throughout the remaining weeks (for Activity-2, *f*=5; Activity-3, *f*=3, and Activity-4, *f*=2).

Robotic Materials

Robotic materials were other necessary equipment for the activities—the participants described the whole robot kit as an essential set of tools in the problem-solving process of the activities. They also separately expressed the robots' pieces, which functioned as essential robot functions as actuating and sensing on the robot kit. *The motors, LED* and *buzzer* as *actuators* and *the temperature, proximity,* and *light sensors* were mentioned during the interviews by the participants for these robotic functions. Besides, the participants referred to other pieces of robots, that worked *outside these functions* such as *the battery* and *connection cable*, as the needed equipment of the activities.

The students reported *the robotic materials* more frequently than the teacher during the data collection process, based on the findings provided in Table 4.33. In detail, only one interviewed student expressed one of the robots' pieces, connection cable, as the required equipment during the interview of Activity-1 (*f*=1) at the beginning of the first cycle implementation. Then, an equal number of students (*n*=4) from the focus group of Activity-2 (*f*=5) and Activity-3 (*f*=8) mentioned these materials during the interviews. At the end of this cycle, one of the students described three of these robotic materials during the focus group meeting.

In the second cycle, six interviewed students expressed *the robotic materials* as needed equipment a high frequency (*f*=7) during the interview of Activity-1. Then, four students described these materials during the interview of Activity-2 (*f*=5). In this cycle, the majority of students' descriptions belonged to seven students interviewed during Activity-3 (*f*=7). However, at the end of the implementation, only one of the interviewed students reported these robotic materials during the interview of Activity-4 (*f*=2) last time. In one of those activities, a group member expressed the use of the sensor as a part of their solution during the interview.

> *C2_A2_FG2_S2: Our robot had some problems in the activity. It was already explained to us on the activity sheet. We prepared such a study for those problems. We tried to stop it so that it would not go in the puddle anymore. Therefore, we moved it with reflection and light sensor.*
>
> *C2_A2_FG2_S2: Etkinlikte robotumuzun bazı sorunları vardı. Bize etkinlik kağıdında da zaten belirtilmişti. Biz de o sorunlara yönelik böyle bir çalışma hazırladık. Su birikintisinde gitmemesi için durdurmaya çalıştık. Onun için yansıma ile ışık algılayıcısı ile hareket ettirdik.*

The needed robotic pieces were also investigated on the activity sheets as one of the parts of the problem-solving process. The purpose of adding these parts, asking the students the necessary actuators and sensors for their solution, was to trigger the students to perform on one of the steps of collecting the necessary data for solving the problem. Along with these parts, the groups were allowed to analyze their needs in the problem-solving process. In one of them, the students had to mark the actuators that they would need in the solution. In contrast, they were expected to draw on the sensors that they thought they were not needed in their solutions in the second part. The responses of the groups were analyzed to reveal the most needed robotic parts. The following graphs were created as a result of the analysis of the relevant sections in the activity sheets.

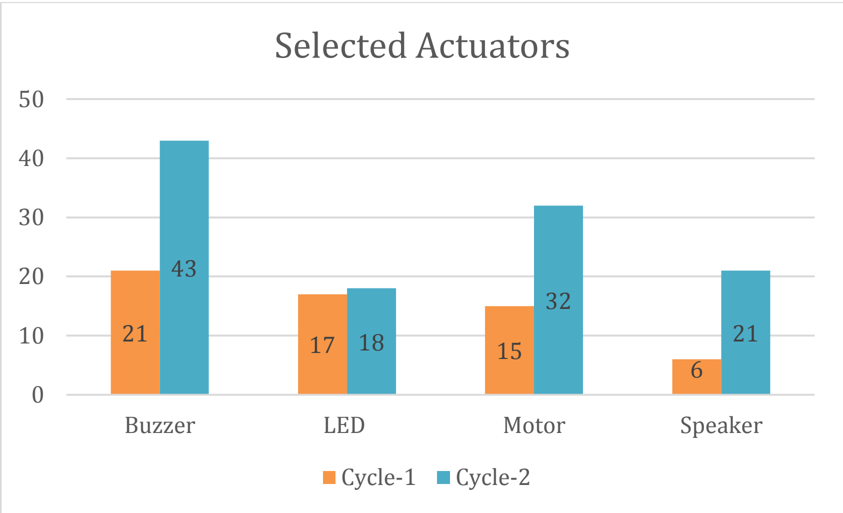

Figure 4-13 Selected Actuators on the Activity Sheets

The frequency of *selected actuators* on the activity sheets in both cycles was illustrated in Figure 4-13. According to this graph, the groups in those cycles mostly preferred *the buzzer* for their solutions during the activities. This actuator was selected by the students 21 times in the first cycle and 43 times in the second cycle. Overall, the second mostly selected actuator was *the dc-motor* which was mostly used for the robot's movement. However, there were solutions in which this dc-motor was used out of its original purpose. For instance, it was used as a propeller in a solution or as a part of a system to open a curtain in another one. In all these usages, it was selected 32 times in the second cycle activity sheets by the students as a part of their solution. This made it the second mostly preferred actuator for this cycle. In the first cycle, it was selected 15 times, which was slightly below of another actuator, *LED light*. The LED was selected nearly in equal frequencies in both cycles. The groups in the first cycle selected this actuator 17 times for their solutions. Similarly, it was chosen 18 times by the students in the second cycle. The last actuator was *the speaker*. In fact, it was the part of a sound card on the robot, and students used it more by loading their own sounds and replaying them in their solutions. This actuator was selected 21 times by the second cycle groups. In contrast, the students of the first cycle chose speakers only six times in their activity sheets.

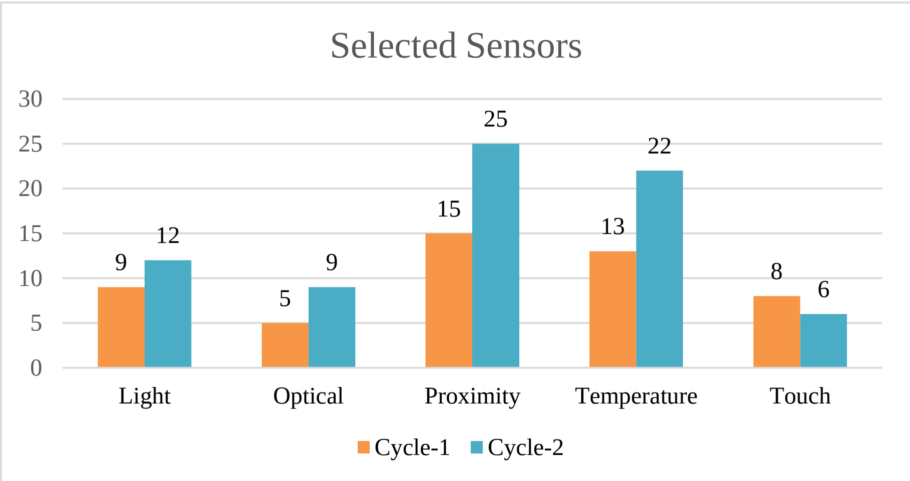

Figure 4-14 Selected Sensors on the Activity Sheets

In Figure 4-14, the frequency of *selected sensors* on the activity sheets was demonstrated for each activity in both cycles. According to this graph, the most preferred sensors of the robot were *the analog sensors* which were exactly *the temperature*, *the proximity*, and *the light sensors*. One of these sensors, the proximity sensor was the most chosen sensor. In fact, it was preferred by the students of the first cycle 15 times in their activities. Similarly, it was also the most selected sensor for the second cycle with a frequency of 25. Another analog sensor, temperature sensor, which was utilized to measure the degree of heat in the environment or an object, was selected by the students of the first cycle 13 times and of the second cycle 22 times. The light sensor was selected 9 times during the first cycle activities and 12 times during the second cycle activities.

The remaining sensors were *the digital sensors*. Among them, *the touch* and *optical sensors* were selected by equal amounts overall, according to the data provided in Figure 4-14. They were chosen total 14 times in both cycles. In detail, the touch sensor was selected in the first cycle activities (*f*=8) more frequently than the activities in second cycles (*f*=5) by the students. In contrast, the optical sensor was preferred by the students of the second cycle nine times in their activity sheets whereas it was selected six times by the students in the first cycle.

Auxiliary Materials

In addition to stationery and robotic materials mentioned above, the *auxiliary materials* were the other equipment of the activities. According to the findings provided in Table 4.33, only two students and the teacher described these extra materials during the interviews of the activities. In detail, one of these materials was expressed by only one student during the focus group interview of Activity-3 (*f*=1) in the first cycle. Similarly, only one of the students described the auxiliary materials during the interview of the same activity in the second cycle (*f*=1). According to these students, *the activity sheet* and *the computers* were the needed auxiliary materials for the activities. Additionally, the teacher mentioned another auxiliary material as equipment during the interview of Activity-1 (*f*=1) in the first cycle. According to him, *the soldering machine* was required for this activity to repair the broken cables on robots. He expressed this as in the following:

> *C1_A1_T: For example, the wheel. While the students were integrating the wheels to the robots, the parts were broken there. We had to solder it again.*
>
> *C1_A1_T: Mesela tekerlek. Tekerleği birleştirirken öğrenciler orada bazı parçalar bozuldu. Onu tekrar lehimlememiz gerekti.*

Structure Level

The equipped activities with stationery, robotic and auxiliary materials were ordered based on the structure level of their problem scenario during the implementation process. According to this sort, while the least ill-structured activity scenario was provided to the students in the first activity, their encounter with the most ill-structured activity scenario was in the last activity in both cycles. Therefore, like their scenario, several characteristics regarding *the level of activities' structure* emerged during the analysis of the collected data. These characteristics were clustered in two main aspects as *unifying factors* and *diversifiers* based on the findings provided in Table 4.34.

Table 4.34 Frequency Distribution of Codes belongs to Category of Structure Level

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Unifying factors	10	-	9	-	12	-	8	-
	Diversifiers	4	8 (*n*=3)	4	2 (*n*=1)	4	3 (*n*=2)	-	-
Cycle 2	Unifying factors	-	1 (*n*=1)	-	-	-	-	-	-
	Diversifiers	1	1 (*n*=1)	-	-	1	5 (*n*=4)	1	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Unifying Factors

The findings in Table 4.34 indicated that *the unifying factors* were reported mostly by the teacher during the data collection process. In detail, he described some of these factors during the interview of Activity-1 (*f*=10) at the beginning of the implementation process. With a close frequency (*f*=9), he reported them during the interview of the second activity. For the remaining weeks, while the majority of his descriptions on these factors belonged to Activity-3 (*f*=12), the frequency of his descriptions declined dramatically during the last activity interview (*f*=8). Moreover, he did not report any of these factors during the implementation process of the second cycle.

In his descriptions, he expressed that *the resources of the activities* were one of the unifying factors of the activities. According to him, *the problem scenario* on the activity sheets among these resources prevented the students from creating different solutions. For instance, the reason for the absence of a solution for drought in the third activity was that drought was not mentioned in the problem scenario of this activity. Additionally, *the limited equipment* of the activities in robotic and stationery materials restricted the students from finding various solutions. The teacher expressed the unifying side of these resources as follows:

> *C1_A1_T: I observed that though there were different points in them, the students' products were similar. They were similar because what we could do with our robot and the stationery materials were limited.*

> *C1_A1_T: Çıkan ürün olarak benzer ürünler olduğunu, arada farklı noktalar var ama hani robotumuzla yaptırabileceğimiz, elimizdeki malzemelerle yaptırabileceğimiz şey sınırlı olduğu için öğrencilerin sonuçlarının benzer olduğunu gözlemledim.*

Additionally, the video watched at the beginning of the activities was one of these resources since the teacher observed that the students just focused on the explanations in the video. According to him, the students were highly influenced by *the video's content* for their solutions. The excerpt from a student's comments on how s/he was affected by the video when filling the activity sheet in the second cycle (Activity-1) supported this observation.

> *C2_A1_FG1_S1: After watching it, we wrote what remained on our mind here (Activity sheet) ... When we watched that video, there were different kinds of robots such as female robots. For example, there was a male robot. They had different jobs there. For instance, there was a gardener robot and a cooking robot.*

> *C2_A1_FG1_S1: Onu izledikten sonra buraya aklımızda kalanları yazdık...O videoyu izlediğimizde orada mesela değişik değişik mesela kadın*

robot vardı. Mesela erkek robot vardı. Böyle onların değişik değişik işleri vardı. Birisi bahçıvan birisi aşçı o tarz robotlar vardı.

In addition to these resources, *the constraints* of activities made the solutions of students quite similar. *The duration* of the activities was one of the constraints, according to the teacher. The students had to find proper solutions in limited time since the duration of the activities was defined with the course hours. Moreover, *the perception of the students* on problem scenario was another limitation of finding various solutions. The students' focus could be affected by this obstacle and resulted in limited solutions. Especially, the effect of perception on the solution process was expressed by the teacher for the third activity which covered all the disability groups.

C1_A3_T: They may not see orthopedically disabled people as disabled, because they can move in a wheelchair, or because they can be more independent than others in terms of being able to move.

C1_A3_T: Belki ortopedik engellileri biraz daha hani tam olarak engelli olarak da görmüyor olabilirler yani çünkü tekerlekli sandalyeyle hareket edebiliyorlar ya da diğerlerine göre biraz daha bağımsız, hareket noktalarında daha bağımsız olabildikleri için.

Diversifiers

Some elements called *diversifiers* worked in the opposite direction of the unifying factors, and they made the structural level of activities more flexible. According to the findings presented in Table 4.34, three students expressed the majority of these elements during the focus group interview of Activity-1 (f=8) in the first cycle. Then, only one student expressed the activities' diversifiers (f=2) after the second activity whereas two students after the third activity (f=3) in this cycle. The findings also indicated that only one student mentioned the elements diversified the activities structure during the interview of Activity-1 (f=1) in the second cycle. Then, four students referred to the remaining diversifying elements during the focus group meeting held after the third activity (f=5) in this cycle.

According to the students, the possibility of *variations in programming* and *the design* opened up the diversifications of the structural level of the activities. In detail, the *use of additional activators* during the programming phase allowed them to produce different solutions. Furthermore, the students came up with different solutions by *designing the robots outside of their normal functions*. For instance, in one of the activities, a group of students created a multifunctional hat. In this design, the robot's wheel was used as a propeller. Like this design, the students reported that they wanted to be different from others in their designs. *This wish* was considered as one of the diversifiers of the structural level of the activities. This indicator of diversifiers implied by one of the students among the groups in the first activity as in the following:

> *C1_A1_FG1_S2: But it was similar to the other teams'but they used two while we used three along with four normal smooth surfaces soours was different.*

> *C1_A1_FG1_S2: Ama diğer takımındaki de aynıydı ama onlar iki tane kullanmış biz üç tane kullandık bir de dört tane normal böyle pürüzsüz yüzey kullandık o yüzden.*

Like the variations in design expressed by S2, *the context of the problem scenario* was one of the diversifiers of the structure level. According to the teacher, the given scenario context in the activity sheet made it easier for the students to visualize that event in their minds and helped them to *create several decisions* that they might not think in that activity, indeed. One of those examples occurred in the second activity wherethe information given in the scenario helped the students to understand the context better and to find various ideas. The teacher expressed this as follows:

> *C1_A2_T: So, without the scenario, this problem would not be understood properly when we asked the students it straightly. The scenario contributed to them to produce even more diverse ideas in their minds.*

C1_A2_T: Yani senaryo olmadan bu problem havada kalıcaktı, yani düz bir şekilde çocukalara da sorduğumuz zaman. Senaryo bize zihinlerinde daha da çeşitli fikirler üretme noktasında katkısı oldu.

According to the findings displayed in Table 4.34, the teacher expressed *the context of the scenario*, *variations in design*, and *programming* as diversifiers of the structure level with equal frequency for the first three activities (*f*=4). Then, the teacher pointed out these diversifiers one by one during the interview of Activity-1 (*f*=1), Activity-3 (*f*=1), and Activity-4 (*f*=1) in the second cycle of the implementation process.

Dynamicity

As a result of the structure of the activities, like the variations in the solutions, the solution paths of the groups were also varied based on several elements. In fact, since the students spent lots of time to solve the ill-structured problems during these activities, it was a quite expected result that there were many factors affecting the solution process in this long time. All these elements indicated us *the dynamicity* of the activities, and were categorized as dynamicity boosters and reducers in the data set provided in Table 4.35.

Table 4.35 Frequency Distribution of Codes belongs to Category of Dynamicity

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Dynamicity boosters	4	2 (*n*=2)	4	2 (*n*=2)	1	4 (*n*=3)	1	-
	Dynamicity reducers	1	1 (*n*=1)	1	2 (*n*=2)	4	5 (*n*=4)	-	-
Cycle 2	Dynamicity boosters	-	6 (*n*=4)	-	5 (*n*=2)	-	4 (*n*=3)	-	-
	Dynamicity reducers	-	1 (*n*=1)	-	-	-	-	-	-

*n *refers to the number of students responsible for the verbal occurrences within interviews*

Dynamicity Boosters

Dynamicity boosters of the activities were reported by the teacher (*f*=10) more frequently than the students (*f*=7) in the first cycle, as seen in the findings provided in Table 4.35. These findings also indicated that the teacher described the majority of these boosters during the interviews of the first two activities (Activity-1, *f*=4; Activity-2, *f*=4) in this cycle. For the remaining activities, he alluded to the booster factors of the dynamicity of the activities with the same frequency (*f*=1), but they were less than the first two. In addition to this drop, he did not defined any of these boosters during the interviews of the second cycle activities.

As an indicator of the change in solution paths of the problems, the teacher emphasized the differences between the groups' algorithms on the activity sheets and the program that used on the robot for the result of the solution. According to him, this dynamic structure of the activities could result from *the use of the resources interchangeability*. For instance, the utilized robotic resources such as buzzer, sound card, light, or temperature sensors were utilized by the students interchangeably during the activities. Therefore, as they reached at the same result, they seemed to change their solution paths by using different robotic pieces. The teacher expressed the increase in the activities' dynamicity resulting from one of those resources such as sound card as in the following:

> *C1_A2_T: Here, we can also include using sensors. In other words, using the sound card was a method that increased the dynamicity positively.*

> *C1_A2_T: Burada agılayıcıları kullanmayı da işin içine katabiliriz. Yani ses kartının kullanılması hani bir dinamikliğini olumlu yönde arttıran bir yöntem.*

Along with resources of the activities, *the proposal creation process* contributed to the dynamicity of the activities. In detail, the students wrote their suggestions for the solution of the ill-structured problem in a section on the activity sheets. According to the teacher, the productivity of the students in this section had a significant impact on the variety of solutions at the end of the activity. One of these parts of activity sheet filled with the solution proposals was given in Figure 4-15. The group of students created two different solutions for hearing impaired and visually impaired individuals in that part, as seen in the figure.

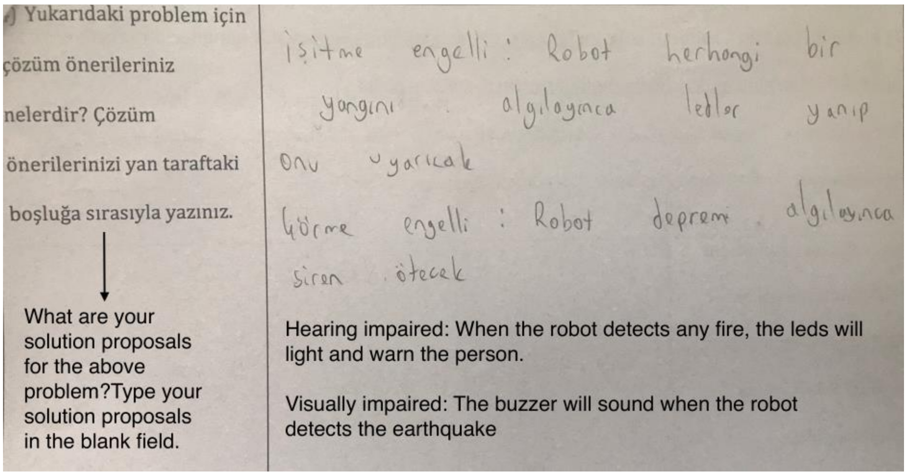

Figure 4-15 The part of Activity Sheet for Solution Proposals

All *solution proposals* described by the students in this part of the activity sheets were counted, and the frequency distribution of these proposals among the activities was illustrated in Figure 4-16.

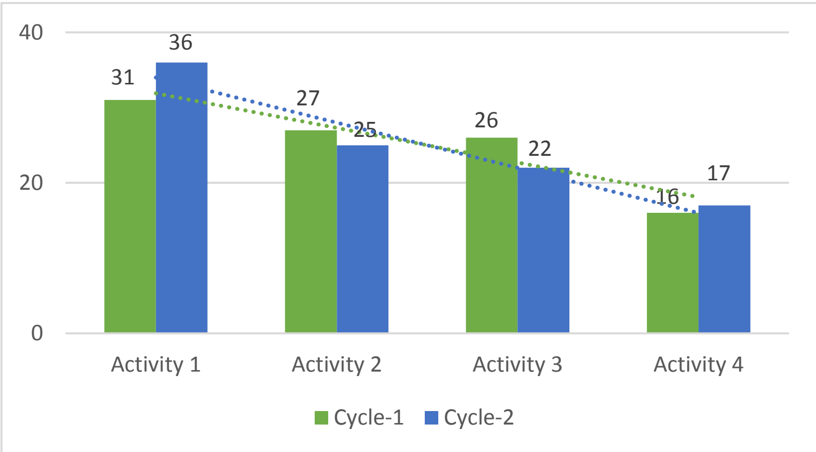

Figure 4-16 The Frequency Distribution of the Solution Proposals

According to this graph, the majority of the proposals in both cycles belonged to the first activities. In detail, 31% of the total proposals in the first cycle (*f*=43) were written into the activity sheets of Activity-1. Similarly, the percentage of the written proposals (*f*=109) was quite high for the same activity (36%) in comparison to other activities in the second cycle. The graph also indicated that these high percentiles of the students' proposals on the first activity sheets declined gradually throughout the implementation process in both cycles. The lowest percentage of the total proposals hereby belonged to the last activity in the first (16%) and the second (17%) cycles.

It was also interesting that the maximum amount of the solution proposals in each activity sheet was seen mostly at the beginning of the implementation process in both cycles, and this amount declined towards the end of the implementation, especially in the fourth activity. In detail, whereas the amount of the maximum solution proposal count belonged to Activity-2 (f=4), it reduced to only one proposal for the last activity in the first cycle. Similarly, the students wrote a maximum of six proposals on the activity sheet during the first week while the students who participated in the last activity wrote only three proposals mostly in the second cycle.

Some students reported that they also reached at *different solutions from the solution proposals* that they wrote on activity sheets during the activity process. The reason for this was that the proposals they created were erroneous and they realized this error in the process. For instance, a group changed their solution paths based on *the feedback* they received from their teachers. Two of the students expressed this modification in their solution paths as follows:

> *C1_A2_FG1_S2: We wrote on the activity sheet first, then it was wrong.*
>
> *C1_A2_FG1_S1: We were excited since the bell would ring soon.*
>
> *C1_A2_FG1_S2: Indeed, we did the same on the computer. The teacher showed it on the computer. He said it was wrong. We fixed this on the computer without thinking about the activity sheet.*
>
> *C1_A2_FG1_S2: Hocam ilk önce buraya yazdık, sonra burası yanlış çıkınca.*
>
> *C1_A2_FG1_S1: Heycanlandık zil çalacak diye.*
>
> *C1_A2_FG1_S2: Sonra aynısını bilgisayara yapmıştık ilk önce. Hoca da bilgisayarda gösterdi. Hoca yanlış dedi. Burayı (kağıdı) hiç düşünmeden bilgisayardakini düzelttik.*

According to the findings presented in Table 4.35, the aforementioned *dynamicity boosters* were reported by the students in almost all activities in the first cycle except for the last one. The majority of these descriptions belonged to three interviewed students of Activity-3 (f=4) in this cycle. During the interview of previous activities, two students individually reported them with equal frequency (f=2). In the second cycle, the four students reported the dynamicity boosters six times during the focus group meeting held after the first activity. Then, two students described them with a high frequency (f=5) during the interview of Activity-2. The remaining descriptions belonged to three students participated in the third activity (f=4). It was an interesting finding that the students who interviewed with the researcher during the last activity did not mentioned the boosters of the dynamicity in both cycles. The potential reasons for this finding were elaborated on in the discussion chapter of the study.

Dynamicity Reducers

In contrast to dynamicity boosters, *the dynamicity reducers* emerged as the factors decreasing the level of dynamicity of activities during the implementation. According to the findings in Table 4.35, these factors were reported by the students more frequently in both cycles than the teacher. In detail, one interviewed student described one of those factors during the focus group meeting held after Activity-1 (f=1). Next week, two students reported them during the interview (f=2). The majority of the descriptions concerning the dynamicity reducers belonged to four students participated in Activity-3 (f=5) in this cycle. In contrast, the students did not refer to any of these factors for the last activity. In the second cycle, only one of the students alluded to these reducers for Activity-1 (f=1).

The elimination of solution proposals was found as one of the dynamicity reducers, depending on the expressions of the students. They explained *the order of priority* as one of the critical reasons for this elimination process. According to them, they applied the solution proposal that came to their mind first. Besides, some of the students added that they did not know how to do the remaining solution proposals. Therefore, they eliminated them. *The inadequacy of resources* was also seen as the reason for the elimination of the proposals. One of these students expressed the insufficiency of the sensors of the robot kit to eliminate one of the solution proposals and apply the other one as in the following:

> *C1_A3_FG2_S1: At first, we were going to make a vibration-sensitive robot against the earthquake, but since there was no vibration sensor, the distance sensor came to our mind as an item would fall in front of the robot.*
>
> *C1_A3_FG2_S1: İlk başta biz depreme karşı titreşime duyarlı bir robot yapacaktık ama titreşim algılayıcı olmadığından bizim aklımıza ilk önüne bir eşya düşeceği için ilk mesafe algılayıcı geldi.*

The teacher also expressed the factor behind the elimination of solution proposals for *dynamicity reducers as the insufficiency of the utilized materials*. Additionally, he emphasized that since the students did not find *solution proposals for each cause* in the activity sheet's fishbone, they were not able to find alternative solutions to those problems. Another reason for the lack of alternative solutions was *the interaction between the groups* during the activity time, according to him. Based on this interaction, the group might have gravitated to the same solutions. He expressed this as follows:

> *C1_A2_T: When we looked at the results, we saw that some groups did the same things ... We can say that being influenced by each other existed a little bit during the activities. This limits us at the point of creating an independent product.*
>
> *C1_A2_T: Çıkan sonuçlara baktığımızda bazı grupların aynı şeyi yaptığını gördük... Birbirinden etkilenme birazcık olabiliyor diyebiliriz. Bu da bağımsız bir ürün oluşturma noktasında bizi sınırlıyor.*

The teacher expressed the aforementioned *dynamicity reducers* in only the first cycle of the implementation. According to the findings presented in Table 4.35, the majority of his descriptions were gathered during the interview of Activity-3 (*f*=4). While he did not report any of these dynamicity reducers during the interview of the last activity, he expressed some of them with equal frequency for the remaining activities (including Activity-1 and Activity-2, *f*=1).

Domain

The domain of these dynamic activities appeared as another structural characteristic of them from the findings of the current study. Several *related fields* were pointed out as associated with this domain by the participants. Some of these fields were directly attributed to the whole structure of the activities, whereas the others were considered as related to the specific parts of them. The findings also indicated that these activities had a close relationship with *the daily life context*. Although this connection was mostly based on the ill-structured problems of the activities, the materials used for them were also seen as an important part of this relation. Both frequency distribution of descriptions for the relation of the activities with other fields and daily life were presented in Table 4.36.

Table 4.36 Frequency Distribution of Codes belongs to Category of Domain

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Related fields	12	-	7	1(*n*=1)	3	-	-	-
	Daily life context	8	-	2	-	1	-	-	1(*n*=1)
Cycle 2	Related fields	1	1(*n*=1)	-	1(*n*=1)	-	1(*n*=1)	3	-
	Daily life context	-	-	-	2(*n*=1)	-	-	-	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Related Fields

According to the findings in Table 4.36, the teacher described *the related fields* of activities more frequently at the beginning of the implementation process. In detail, he expressed most of the fields for the activities during the interview of Activity-1 (*f*=12) in the first cycle. However, this cycle resulted in lower frequencies of teacher's descriptions regarding the related fields of the given activities, which showed a gradual decline throughout the rest weeks (including Activity-2, Activity-

3, and Activity-4). Moreover, in the second cycle, the teacher referred to one of the domain fields during the first meeting placed for the Activity-1 (*f*=1) at the beginning of this cycle. Then, he mentioned the related fields again three times during the interview of Activity-4 (*f*=3) at the end of the cycle. In summary, the results regarding the distribution of frequency concerning the teacher's descriptions about related fields of activities varied for two cycles. While the related subject domains mostly expressed by him at the beginning of the first cycle (for Activity 1), reversely, these related fields were mostly uttered at the end of the second cycle (for Activity 4). The potential reasons for the reversed findings were elaborated on in the discussion chapter.

The teacher described the given activities as interdisciplinary in nature due to their integrated structure to different subject domains. According to him, *science* and *instructional technology* fields were the prominent subject domains in the given activities. In addition to the teacher's perception regarding these fields of activities, the students needed to use special skills related to other subject domains during the activities. For instance, the students required to use linguistic skills to fill the activity sheet during the first phase of the activity process. Therefore, the activities were closely interrelated with the *Turkish course* for him. *The art* and *engineering fields* were also implicitly related with the remaining phases of the activities. One of the expressions of the teacher about these related fields of activities was as in the following:

> *C1_A1_T: I think it is related to the field of industry, engineering, and science, instructional technology courses and the art field with handcraft and design points in it.*

> *C1_A1_T: Fen bilgisi dersi, bilişim dersleri, sanayi alanı, mühendislik bu alanlarla ve el becerisi ve tasarım noktasında görsel sanatlar alanıylailişkili olduğunu düşünüyorum.*

In addition to the teacher's verbal accounts, the frequencies of the student's descriptions were separately illustrated in Table 4.36. According to findings in this table, the students described *the related fields* as the domain of the activities with a lower frequency in comparison to the teacher's descriptions. The findings also showed that not all the fields in the descriptions of the teacher were reported by the students. Only *the science course* was expressed as the related field for the activities by one student among five interviewed students at the end of Activity-2 (*f*=1) implemented in the first cycle. Similarly, a student from the student groups during Activity-1 (*f*=1), Activity-2 (*f*=1), and Activity-3 (*f*=1) reported the same course as the domain of the activities in the second cycle. Among these students, the student interviewed in the third activity expressed two other related fields as *instructional technology, social and science fields* as the related fields for that activity.

> *C2_A3_FG3_S3: Teacher, it contains social, instructional technology, science since it says earthquake so on.*

> *C2_A3_FG3_S3: Hocam sosyal, fen ve bilişim deprem falan dediği için onları da kapsıyor.*

The excerpt of S3 implied that the student interrelated the subject domains with social sciences, information technology, and science by referring to the keyword, "earthquake" included in Activity-3. Although this keyword was utilized to make the activity ill-structured in reference to real-life scenarios, student's perception regarding the domain of the activity was shaped since the activity was also related to the social sciences.

Daily Life Context

Like the aforementioned domains as a related field, the activity was perceived as associated with *daily life context* by some students. According to findings in Table 4.36, one of the students reported the connection of activity with daily life during the interview of Activity-4 (*f*=1) in the first cycle by seeing the ill-structured problem in that activity as *one of the daily life problems.* Similarly, only one student among the interviewed 11 students in Activity-2 expressed the connection of daily life two times (*f*=2) during the focus group meeting. According to this student, *the sensors on the* *robot* enabled this relation since they were utilized in several parts of our daily life. Additionally, some of *the robotic resources* were very similar to human organs so the activity evoked daily life for him/her.

In summary, the students commented on the connection of *the daily life* with the activities during the interviews of implementation process. However, the activities and the reasons behind this connection were different for the students in both cycles. The activity in the second cycle referred to the second activity took place in the middle of the implementation and *the robotic pieces* were seen as the reason for the connection in this activity. On the other hand, the connection of activities with the daily life established for the last activity at the end of the implementation process in the first cycle since *the problem* used in this activity had a high similarity with daily life problems. The comment of this similarity during the focus group meeting was as in the following:

> *C1_A4_FG1_S2: They are out there, they throw trash on places, and they pollute the world but then they say why I live in such a place.*

> *C1_A4_FG1_S2: Dışarıda var, atıyorlar yerlere çöp ve dünyayı kirletiyorlar sonra diyorlar niye böyle bir yerde yaşıyorum.*

The connection of activities with *daily life* was also touched upon by the teacher. Like his students, *the proximity of ill-structured problems in activities with daily life* was seen as one of the major reasons for this connection. In fact, he thought that the students encountered the ill-structured problems in daily life itself during the activities. Therefore, they needed to know daily life experiences to cope with that problem. In the struggle for the solution process of this problem, *the robots* gave the students the opportunity to use daily life technology. Hereby, the students got the chance to practise with the daily life technology in these activities. As a result of this practice, the proximity between the activities and daily life became closer to the students' solutions. One of the explanations of him about these solutions was presented in the following:

C1_A1_T: We talked about a problem in daily life, and it was a problem they knew. They have already found solutions in daily life. I got feedback that they used winter shoes, or winter tire, or chains.

C1_A1_T: Günlük hayattaki bir problemden bahsettik, bildikleri bir sorundu. Ve buna zaten kendileri günlük hayatta çözümler buluyorlar. kışlık ayakkabılar gibi, ya da arabalara tekerlek takıyo, zincir takıyoruz hocam gibi dönütler aldık.

According to the findings presented in Table 4.36, the relation of the activities with *daily life context* was reported by the teacher only in the first cycle. His descriptions concerning this relation were quite high at the beginning of the implementation process, especially during the interview of the first activity (*f*=8). However, the frequency of his descriptions decreased progressively throughout the remaining weeks in this cycle of the implementation. It was surprising that the relation of the activities with daily life were not reported during the interview of the last activity in this cycle and all the activities in the second cycle. The potential reasons for this unexpected result were expanded on in the discussion chapter.

Instructional Features

The second theme to reveal the characteristics of the activities in the current study was found to be the *instructional features* of them. According to the findings, these features of activities were divided into four main categories: *transfer*, *credibility, practice,* and *teacher role.*. The theme and the related categories were illustrated in Figure 4-17. The weight of each category composed of the codes counts was represented with the thickness of the lines in this figure.

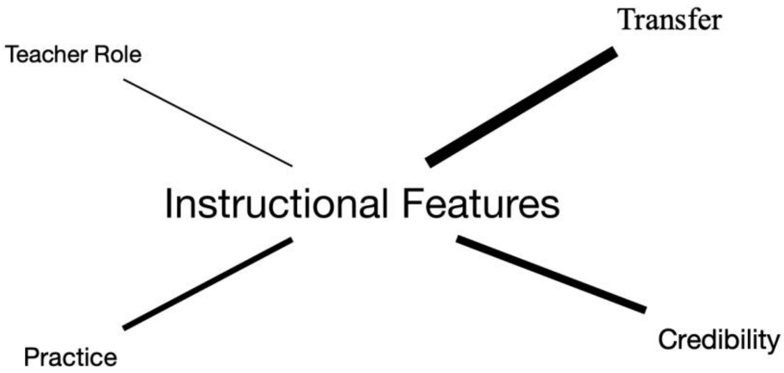

Figure 4-17 Categories of Instructional Features

The main data sources for these categories were the interviews with the teacher and the students in both cycles of the implementation. A code tree including categories of the theme and the related codes listed based on the count of participants' descriptions during the interviews was presented in Table 4.37. Each category and the codes were elaborated on one by one after this illustration.

Table 4.37 The Code Tree of Instructional Features Theme

Categories/Codes	Σf
Transfer	**91**
Daily life	44
Professional life	25
Project	16
Education	6
Creditability	**81**
Aimful	46
Explainable	26
Evaluable	9
Practice	**41**
Active participation	26
Applicable	15
Teacher Role	**31**
Active	28
Inactive	3

Transfer

One of the specific instructional features of the activities was transferable aspects of them. These aspects were revealed by the participants who reported that *the transfer* of these activities as possible to *daily life*, *professional life*, *projects*, and *education*. In some of these areas, such as professional and daily life, the transfer of the whole activity or the product developed as the solution to the problem was possible for some of the participants. Another point of view mostly showed other transfer areas. This view agreed that what learned during the activities could be transferred to those areas such as other projects and future education. The frequency distribution of the participants' descriptions for all these transfer areas was presented in Table 4.38.

Table 4.38 Frequency Distribution of Codes belongs to Category of Transfer

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Daily life	1	3 (*n*=3)	-	6 (*n*=3)	-	7 (*n*=3)	-	1 (*n*=1)
	Professional life	1	5 (*n*=3)	-	-	-	1 (*n*=1)	-	-
	Project	-	1 (*n*=1)	-	1 (*n*=1)	-	1 (*n*=1)	-	-
	Education	-	5 (*n*=3)	-	-	-	-	-	-
Cycle 2	Daily life	-	5 (*n*=4)	-	8 (*n*=6)	-	11 (*n*=7)	-	2 (*n*=2)
	Professional life	-	3 (*n*=2)	-	5 (*n*=4)	-	5 (*n*=3)	-	5 (*n*=4)
	Project	-	4 (*n*=3)	-	3 (*n*=3)	-	2 (*n*=2)	-	4 (*n*=2)
	Education	-	-	-	-	-	1 (*n*=1)	-	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Daily life

According to the findings in Table 4.38, all the transfer areas were reported by the students with a higher frequency in comparison to the teacher's descriptions during the implementation process. One of these areas, *daily life*, was defined by the students for all the activities in both cycles. At the beginning of the implementation process, three of four interviewed students during the focus group meeting of Activity-1 commented on the transfer of the activities to the daily life firstly (*f*=3).

The frequency of the students' descriptions continued increasingly until the last activity in this cycle. The highest frequency of these descriptions belonged to three students who participated in the focus group meeting of Activity-3 (f=7). On the other hand, only one student during the interview for Activity-4 touched upon this transfer area (f=1) lastly in this cycle.

The similar frequency distribution of the descriptions concerning *the transfer of activities to daily life* was also seen for the students participating in the implementation during the second cycle. Among the activities in this cycle, four students for Activity-1 reported the possibility of transfer of this activity to daily life five times during the focus group meeting (f=5). The frequencies of the descriptions of the students interviewed in other activities increased gradually until the last activity as in the first cycle. Seven students during the interview of Activity-3 reported the transfer of activities to daily life most frequently (f=11) in this cycle. In contrast, two students interviewed for Activity-4 commented on the transferable aspect of the activities quite less frequently (f=2) in comparison to other activities.

According to the students' descriptions in the focus group meetings, *the transfer of the activities to daily life* was seen in two different ways. In one of them, the students would use these activities *individually*. Students claimed that they could use the technology in activities during their daily life. For instance, one of the students commented during the interview that he/she would use this technology *while using the electronic devices in daily life* since they learned how to use the technological materials such as batteries, voice cards, and circuit switch during the activities. Additionally, robots could ease the students' daily life *by helping them* in their daily worksuch as doing housework. Beside to this general usage, one of the students expressed that using the solution for the robots in the first activity could be used in cars in daily life. S1 expressed this as in the following:

> *C2_A1_FG2_S1: I think it can also be used in our daily life, so if we think the robot as a car, it can be seen when the light shines thanks to the light (sensor) while driving in the car.*

C2_A1_FG2_S1: Bence günlük hayatımızda da kullanılabilir yani robotu araba olarak düşünürsek, arabada giderken mesela fener sayesinde ışık parıldayınca hani gözükebilir.

The excerpt of S1 provided a basis that the usage of the technology in the problem-solving activities were seen as transferable to daily life for the students. Based on this, the students' solution to the problems was seen as transferable *for the similar problems in daily life*. The similarity of the ill-structured problems to the problems in their daily life was the key point for the transfer here. One of the students expressed the use of their solution for the problem of being hot in daily life. The supporting text and the drawing of this student (Figure 4-18) were as follows:

C2_A2_D_S4:

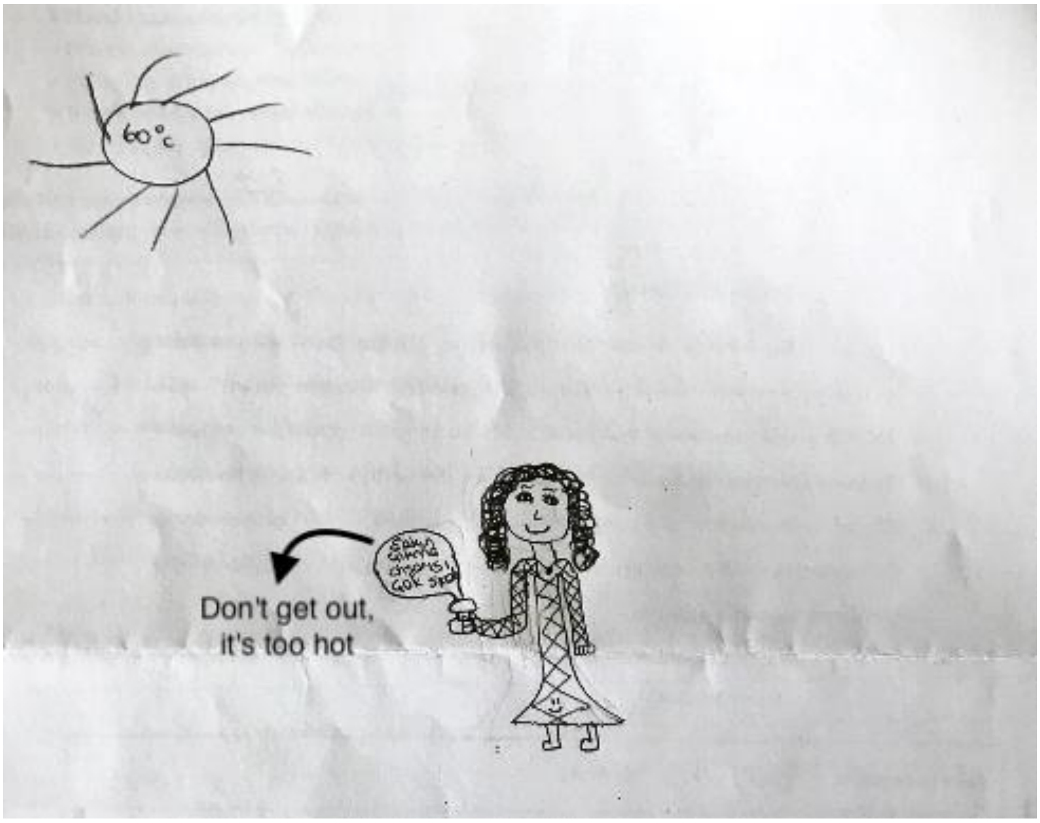

Figure 4-18 Drawing of S4

S4: "I'm going out. I have my robot with me. It warns me when the weather is hot. While I am walking, my robot gives me an alarm meaning: Do not get out; it is too hot outside. In this way, I am protected from diseases and harmful lights of the sun."

S4: "Ben dışarıya çıkıyorum. Yanımda da robotum var. Hava sıcak olduğunda o beni uyarıyor. Ben yürürken robotum bana dışarısı çok sıcak gitme anlamında alarm veriyor. Ben de bu sayede hastalıklardan ve güneşin zararlı ışıklarından korunmuş oluyorum."

In addition to individual use, the activities were also transferred to *daily life to help others* in several ways, according to comments of the students. In one of them, the transfer of these activities was possible for *protecting the health of other people*. Moreover, some of them thought that they could *help disabled people* thanks to these activities. One of the students expressed that the solution of them could be upgraded. Then, it could be used by disabled people during natural disasters by saying the following:

C1_A1_FG3_S2: For example, we can improve our robots and turn them into products for sale. For example, disabled people buy this. It can be used when there is a natural disaster by these disabled people. Since we used a buzzer, other people can hear its voice. Security aids can come and rescue people with disabilities from where the natural disaster occurred.

C1_A1_FG3_S2: Robotları mesela geliştirip bunları satış haline getirebiliriz mesela engelliler bunu alır. Doğal afet olunca kullanabilir. Diğer insanlar da mesela siren kullanacağı zaman, diğer insanlar sirenin sesini duyabilir. Yardım, güvenlik yardımcıları gelip engellileri doğal afetin olduğu yerden çıkartabilir.

As seen in the excerpt of S3, the use of activities *to help others* was very similar to individual usage since they were in conjunction with the scenario of the ill-structured problem. However, students' explanations for using these activities for others were not limited to this. Several students who reported that they would *teach their learnings in these activities to their relatives* offered a different perspective on the transfer of activities. From this perspective, two different teaching time periods as *recent* and *future* were seen among the students' descriptions. While some of the students mentioned that it might be possible to transfer what they learned in this activity to their next generations, the others reported that they already taught their relatives what they acquired in the activities. One of these students expressed this type of transfer as follows:

> *C1_A2_FG2_S1: For example, we tell our families what we learned here. Therefore, they also learn.*
>
> *C1_A2_FG2_S1: Mesela burada öğrendiklerimizi ailelerimize anlatabiliyoruz onlar da öğreniyorlar.*

Despite the intense explanations of the students, the teacher made only one explanation about *the transfer of the activities to daily life*. The teacher expressed it at the beginning of the implementation during the interview of Activity-1 (*f*=1). According to him, the students could use these activities *as a hobby* in their future daily life.

> *C1_A1_T: The students in their profession choice, or as a hobby and as an interest, can use the robots and robotic coding in the activities.*
>
> *C1_A1_T: Çocuklar ilerideki meslek seçimlerinde ya da meslek seçimi olmasa bile bir ilgi bir hobi olarak düşündüğümüz zaman, robotları, robotik kodlamayı içerisine alan aktiviteleri kullanabilirler.*

Professional Life

The excerpt from the teacher also implied that the students might use the activities in their professional life. In addition to this implication, *the transfer to professional life* was also expressed directly by him during the interview of Activity-1 (*f*=1) in the same cycle. With this expression, the teacher emphasized that the activities could be effective on students' *professional choice*. He expressed this as the following:

C1_A1_T: Some of my students asked which department I completed, and at which university I studied. My teacher, how do you know these? Did you study these in college or high school? When did you study? How can we learn them? Or, can we make a robot differently? After this activity, some of them said they would be an information and computer technology teacher. I got such questions and feedback during this activity. I received feedback from them that they might be affected in future professional choices by these activities.

C1_A1_T: Öğrencilerimizden bazıları benim hangi bölümü bitirdiğimi, hangi üniversitede okuduğumu sordular. İşte hocam siz bunları nereden biliyorsunuz? Üniversitede mi gördünüz, lisede mi? Ne zaman gördünüz? bu etkinlikten sonra da ben bilgisayar öğretmeni olacağım şeklinde ya da hangi bölümü bitirdiniz hocam? Biz bunları nasıl öğrenebiliriz? ya da başka şekilde robot yapabilir miyiz? diye bu şekilde dönütler geldi. çocuklar Hani ilerideki meslek seçimlerinde bu etkinliklerden etkilenebileceklerine yönelik dönütler aldım.

Three students also reported the effects of the activities on *the choice of the profession* during the interviews of the same activity. The common point here was that students tended to change the professions they previously chose. It was interesting that this trend was toward *the technical fields*. The comment of one of these students about this tendency was as follows:

C1_A1_FG1_S3: For example, maybe I can change my profession when I grow up. I want to be an engineer, and then we might need it, for example.

C1_A1_FG1_S3: Mesela ben de belki büyüyünce mesleğimi değiştirebilirim. Bende mühendis olmak isterim o zaman mesela lazım olabilir bize.

In addition to the change of profession, some of the students reported that they would choose professional fields in which they would benefit from these activities. These professional fields emerged mostly as *teacher, engineer, and scientist*. The students who decided to choose these professions were sure that they would use these activities in the future professional life. Along with these fields of expertise, several students commented that they would benefit from these activities in *other occupational groups* which *required technical knowledge* such as a pilot or in relatively *social occupations* such as judge and cooking. Among the technical fields, one of the students expressed the benefits of these activities when choosing technical fields as a profession as follows:

> *C2_A4_FG1_S1: In the future, for example, if we become a computer engineer or IT teacher, we can benefit from the information in the activity.*

> *C2_A4_FG1_S1: Gelecekte mesela bilgisayar mühendisi falan olursak ya da bilgisayar öğretmeni bu bilgilerden faydalanabiliriz.*

According to the findings provided in Table 4.38, the students described the transfer of the activities to *professional life* more frequently at the beginning of the implementation process in the first cycle. In this cycle, three students expressed several of the professional fields and the effect of the activities on professional choice during the interview of Activity-1 (*f*=5) firstly. One among six interviewed students also reported the transfer of activities to the professional fields during the focus group meeting of Activity-3 (*f*=1) in this cycle. In the second cycle, the students referred to this transfer throughout all the activities. At the beginning of the implementation, two students mentioned this during the focus group meeting of Activity-1 (*f*=3) three times. In the remaining activities, the transfer of activities was expressed with equal frequencies (*f*=5) by four students during the interview of Activity-2, by three students during the interview of Activity-3, and by four students during the interview of Activity-4.

Projects

The findings in Table 4.38 also indicated that the frequencies of the students' descriptions for the transfer of activities to *the projects*. The students started to describe this type of transfer at the beginning of the implementation. In detail, one student expressed the transfer of the activities to the projects during the interview of Activity-1 (*f*=1) firstly in the first cycle. In all interviews in this cycle, except for the last activity, one student repeated this feature of the activities. In the second cycle, the transfer of the activities to other projects was on the agenda of the students who participated in focus group meetings throughout the implementation process. At the beginning of this cycle, three students firstly reported it during the interview of Activity-1 (*f*=4). Three students during the interview of Activity-2 (*f*=3), two students for the third activity (*f*=2), and two students for the last activity (*f*=4) also commented on the transfer of the activities to other projects.

Among the transferred projects, *the invitations* that the students wanted to make were at the forefront. In all these invitations, the focus of the students' explanations was on *the use of robots*. Among them, some of the students expressed the projects for which they would make their own robots. Another part of them commented that they aimed to upgrade the robots they used for the solution in the activity for new projects. For instance, a group of students designed a swing-sensitive bed to alert people with disabilities in the earthquake during the third activity in the first cycle. One of the students in this group stated that they could adapt the system in this solution to a situation such as a child care as follows:

> *C1_A3_FG1_S1: A different idea came to my mind. For example, the mother and father are sleeping here, the child is sleeping here, in a cradle, in the evening. The mother's sleep is a little bit deep. After that, the baby wakes up and cries. As he/she cries, the cradle starts shaking. Therefore, it touches the device, then it rings. This awakens the mother. The mother learns that the child is getting up. So this looks very similar to our solution.*
>
> *C1_A3_FG1_S1: Hocam benim aklıma değişik bir şey geldi. Mesela şimdi akşam anneyle baba burada yatıyor çocuk da burada uyuyor beşiği var. Cihaz da bunun yanında annenin tabi uykusu biraz derin. Ondan sonra bebek ayağa kalkıyor ve ağlıyor. Ağladığı sırada beşik sallanıyor. Bu beşik*

buna temas ediyor o sırada ötüyor bu. Bu da anneyi uyandırıyor. Anne çocuğun kalktığını öğreniyor. Buna çok benziyor yani.

The transfer of the activities to *other projects* was also related to the students' experience in the activities. The students felt they were lucky since they were knowledgeable about these kinds of activities. Therefore, they could use their knowledge for other activities or projects. One of the students who reported the use of this knowledge in solving similar problems as in the following:

> *C2_A3_FG5_S1: I learned that because the room temperature is around 20, for example, I will choose 27 when programming the robot so that we can do it directly in the future.*

> *C2_A3_FG5_S1: Ben şunu öğrendim oda sıcaklığı 20 civarı olduğu için mesela ileride de böyle yapacağımızda direk yapabilelim diye robotu programlarken 27'yi seçerim.*

Educational Life

In addition to the advantage of these activities in similar projects, they were also beneficial for *the future educational life* of the students. Like for the projects, a few students expressed that they could use the information acquired in these activities throughout their remaining education life. The emphasis on the educational life was on *the higher education level* here. However, there were also two students who reported that they could benefit from the activities *in high school*.

Overall, the transfer to these education levels was described mostly by three students at the beginning of the implementation for Activity-1 (f=5) in the first cycle. In the second cycle, only one student expressed the transferable aspect of the activities to the remaining *educational life* during the interview of Activity-3 (f=1), according to the findings in Table 4.38. One of those students maintained that doing these activities would take advantage in university education to himself/herself as follows:

> *C1_A1_FG1_S2: Maybe I will do something like that at university, and I can do better than my friends there.*

C1_A1_FG1_S2: Belki üniversitede de böyle bir şey yapacağım ve arkadaşlarımdan daha iyi yapabileceğim.

Credibility

Credibility was found as another instructional characteristic of the activities, based on the data analysis. According to the participants' expressions, the aim of the activities, explanations about them, and evaluable aspects of the activities contributed to the credibility of the activities. To give it a more detailed manner, one of the indicators of credibility showed that each activity had a certain aim, and *being aimful* made them credible to others. Additionally, *the explainable side* of them indicated that the whole activity process and the solutions of the ill-structured problems were presented to others easily, which also contributed to the creditability of the activities. The last indicator of the credibility of the activities was that they were *appropriate for evaluation*. The frequency distribution of descriptions of the participants on these three indicators of the creditability was illustrated in Table 4.39.

Table 4.39 Frequency Distribution of Codes belongs to Category of Credibility

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Aimful	2	3 (*n*=3)	2	1 (*n*=1)	-	8 (*n*=4)	-	1 (*n*=1)
	Explainable	-	2 (*n*=2)	-	1 (*n*=1)	-	1 (*n*=1)	-	3 (*n*=2)
	Evaluable	3	-	1	-	1	-	1	-
Cycle 2	Aimful	2	5 (*n*=4)	2	4 (*n*=3)	-	7 (*n*=6)	1	8 (*n*=5)
	Explainable	-	6 (*n*=6)	-	3 (*n*=3)	-	6 (*n*=6)	-	4 (*n*=3)
	Evaluable	-	-	-	1 (*n*=1)	-	-	2	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Being Aimful

According to the findings provided in Table 4.39, the teacher mostly described the aim of the activities at the beginning of the implementation in the first cycle. During the interviews of the first and the second activities, he expressed the aim of the activities (*f*=2) with equal frequency. He did not referred to it for the activities in the remaining weeks of this cycle. In the second cycle, similarly, he reported two times the activities as aimful during the interviews of the first two activities. He repeated the description of the aim of the activities one more time during the interview of Activity-4 (*f*=1) at the end of the implementation. In conclusion, the distribution of the teacher's explanations of *the aimful side* of the activities was similar in both cycles. In fact, the results regarding the distribution of the frequency on the teacher’s descriptions about the aims of the activities were mostly gathered in the activities at the beginning of implementations in the cycles.

The teacher alluded to *the general goals* of the activities firstly during the interviews. According to him, these general goals of the activities were *solving problems*, *developing a product*, and *using educational robots*. Accordingly, the students encountered a problem at the beginning of the activities. Then, they created algorithms on educational robots to overcome that problem. In order to solve the problem, they also needed to make a product as the result of the design phase of the activities. For this production, the teacher preferred to share the goal of the activities with the students at the beginning of the second activity as follows:

> *C1_A2_T: In our activity today, I told the students that our aim was to learn byspending a pleasant time while learning, and to produce something new.*
>
> *C1_A2_T: Çocuklara bugünkü etkinliğimizde ilk olarak amacımızın öğrenmek, öğrenirken de sıkılmadan güzel bir şekilde keyifli vakit geçirerek öğrenmek ve yeni bir şeyler üretmek olduğunu söyledim.*

The students’ expressions were different from the teacher’sabout the goal of the activities, and they mostly pointed out *activity-based aims* rather than general goals. For instance, the students aimed to *upgrade the robots* during the first activity to prevent them from slipping. In the second and the third activity, the students argued that the aim of the activity was to *protect people*. In detail, they explained this protection process mostly in relation to themselves in the second activity. In the third activity, the aim was mostly to protect other people, especially disabled people. In the last activity, the protection was mostly seemed to directed towards the environment. One student in a group that developed a robotic dustbin to *protect the environment* during this activity in the second cycle defined the purpose of what they did as follows:

> *C2_A4_FG2_S4: The bread or food residues should not be thrown away. Putting them in this vehicle that we did and deliver them to the animals earlier.*

> *C2_A4_FG2_S4: Hocam, ekmeklerin yani yemek artıklarının çöpe atılmaması, onların bu yaptığımız araca koyulup daha erken hayvanlara ulaştırılması.*

S4 also implied that the aim of the activities went beyond what was expected in the scenario of the ill-structured problem presented in the activity sheet. Although only a problem scenario related to environmental pollution had been presented in this activity sheet of the last activity, it was surprising that the students here set a goal that included the feeding of stray animals besides environmental protection.

Another interesting finding of this code was about the difference between teacher's and students' descriptions of activity goals. While the teacher mostly reported *the general goals* of the activities such as problem-solving and using educational robots during the interviews, the students mentioned *the activity-based goals* which were compatible with the activity scenarios. These goals were aligned with protecting robots, themselves and other people, disabled people, and the environment, based on the activities' sequence. The potential reasons for these two findings were discussed in detail in the discussion part of the study.

Being Explainable

Just as the students explicated on the purposes of the activities during the interviews, they also explained the process of the activities very easily. In fact, to reach at these explanations, the students were asked to think that a friend in their classroom who did not come to that activity, and they were asked how they would describe the activity to their friends during the focus group meeting. Additionally, each group presented their solutions to the teacher and other friends at the end of the activities. The fact that students easily explained the activity process during the interviews and shared their products with others comfortably indicated that these activities were *explainable* for others as an instructional characteristic.

One of the drawings indicated *the explainable aspect of the activities* in the reflection paper. In this drawing, the student explained the activities with his/her own words in the supporting text field. The student wrote that he/she drew the time of introducing her robot to the teacher and friends during the activity. The drawing (Figure 4-19) and the supporting text was as follows:

C2_A2_D_S5:

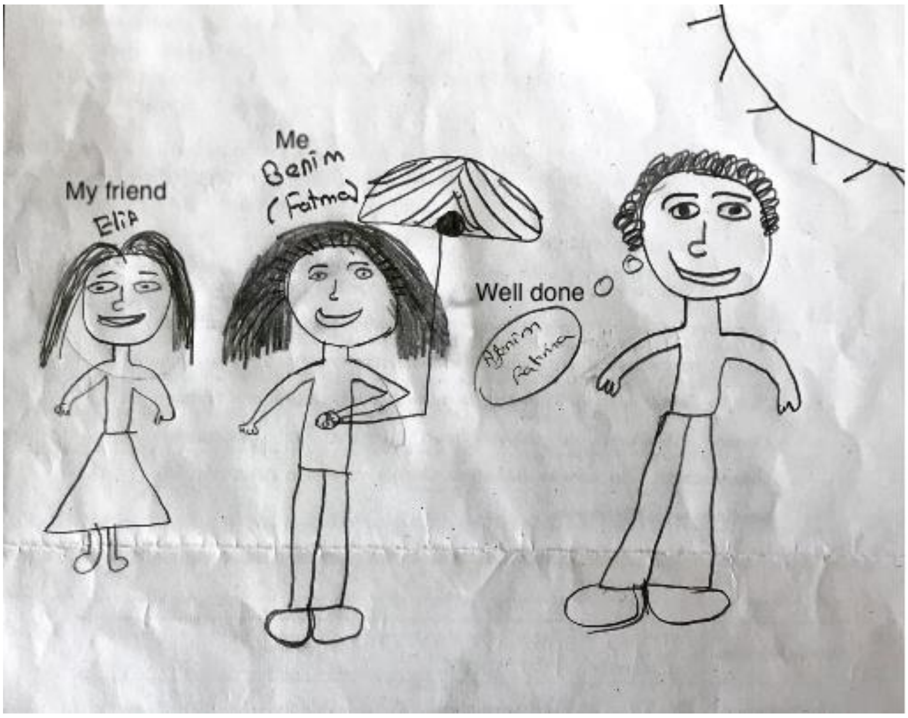

Figure 4-19 Drawing of S5

S5: "In this drawing, I introduce my robot. My umbrella robot works like this. It warns me when the sun hits me a lot and the buzzer sounds."

S5: "Ben bu resimde robotumu tanıtıyorum. Şemsiye robotum şöyle bir işe yarıyor güneş bana çok vurunca beni uyarıyor ve siren çalıyor."

According to findings provided in Table 4.39, the student *explained the activity process* easily during the focus group meetings throughout the implementation in both cycles. Most of them emphasized *the design issues of their products*. For instance, two students explained their design for the solution to the problem as they stopped the robot when moving from a rough surface to a smooth surface and moved it again on the rough surface after changing the direction in the first activity at the beginning of the first cycle (*f*=2). One of those explanations was as follows:

C1_A1_FG1_S1: As the robot slips, we thought of a method like this: it stops when it passes from slipping to the rough surface, the siren sounds, the led lights, then it continues on its way without slipping.

C1_A1_FG1_S1: Hani robot kaydığı için biz de şöyle bir yöntem düşündük pürüzsüz yerden pürüzlü yere geçerken duruyor şey siren çalıyor Işık şey yapıyor led yanıyor sonra yoluna devam ediyor yani kaymadan.

In a similar vein, one student explained their design-based solution like this: they developed an air temperature-sensitive robot during the second week in the first cycle (*f*=1). This robot helped people with the warning of the hot air. In this explanation, the student expressed the design of sun, beach, and the sea more than the other issues in their solution. Additionally, two students describedhow they designed a sample dustbin (*f*=2) during the last activity in this cycle. Along with these *design-based explanations,* the explanation of a student in the fourth activity covered mostly the technical dimension of activities (*f*=1). This *technical explanation* was as in the following:

C1_A4_FG1_S1: We first used an optical sensor. It detects whether it is black or white; it detects it first. It detects everything in the environment. After that, as soon as it sees the rubbish, the buzzer sounds for five seconds, *and the led lights for 3 seconds. After that, it is like this if it is closed color, but if it is a light color, we tied it to the beginning of the algorithm.*

C1_A4_FG1_S1: İlk önce optik algılayıcı yaptık siyah mı beyaz mı ilk önce onu algılıyor. O ortamda ne var ne yok her şeyi algılıyor. Ondan sonra, onu gördüğü an ilk önce beş saniyelik led yanıyor pardon beş saniye siren çalıyor ve 3 saniye de led yanıyor. Ondan sonra da kapalı renkliyse böyle oluyor, açık renkliyse de onu başa bağladık.

In the second cycle, the students explained the activities with both aspects i.e, *design-related* and *technical*. The weight of the frequencies of six students' explanations was equal for the first and the third activities (*f*=6), and these activities contained the majority of the frequencies in this cycle. Similarly, two students interviewed during the second activity mentioned the design-related and technical explanations about the activities (*f*=2). In this activity, one of the students' explanations emphasized that he/she presented the activity to other people (*f*=1). Similarly, one of the students also expressed that he/she presented these activities to relatives during the third activity interview (*f*=1). These explanations indicated that the activities were appropriate to present to others not only activity connected individuals such as their friends and the teacher but also to those who were not connected. One of the students who found the activity to be presentable to the others stated during the last activity that they could be presented to institutions and organizations:

C2_A4_FG1_S1: For example, if we presented this activity to the Ministry of Health and made the robots go throughall over, it would be great since microbes can infect people. Thus we would protect them.

C2_A4_FG1_S1: Mesela biz bu etkinliğimizi sağlık bakanlığına iletsek böyle her tarafta robotlar gezdirsek iyi olur çünkü sağlık amacıyla insanlara mikroplar bulaşabilir. O yüzden korumuş oluruz.

To sum up, the students explained the activities and disclosed their solutions in these activities in several ways during the data collection process of the study. The explanations were mostly *design-related*. *The technical explanations* about their solutions were also considerable. The explanations of the students also indicated that they had presented the activities to the close circle of the activities such as *the classmates* and *the teacher* and *others* who were not related to the activities. All these explanations offered that the activities were explainable.

Being Evaluable

Being evaluable was another instructional feature of the activities that contributed to their credibility. According to findings in Table 4.39, the teacher expressed the activities with possible evaluation aspects that contained several grading tools such as product evaluation, activity sheets, and peer assessment forms. He reported these aspects of the activities mostly in the first cycle. In detail, they were described by him more frequently during the interview of the first activity (*f*=3). The teacher continued his discourses in the same direction equally in the remaining weeks in this cycle (including Activity-2, Activity-3, and Activity-4, *f*=1). Moreover, in the second cycle, the teacher touched upon the evaluable side of the activities during the last meeting placed for the Activity-4 (*f*=1) at the end of this cycle.

In his descriptions, the teacher expressed that he got opportunity to check the learning status of students via these activities. As these activities covered the topics throughout the whole semester, they enabled *a general evaluation* for him. The teacher maintained that he observed students in activities while making this general assessment for grading. Furthermore, *the activity sheets* or *students' products* could be used for the same purpose. He expressed that *the peer evaluation forms*, in which the students used to assess the group members in the second cycle, was very useful in the evaluation of students in addition to teachers' observations during the activities.

> *C2_A4_T: I think this evaluation method is very useful because we only observed the work of the children in the group while evaluating the students previously. We were making an external observation, but we couldn't see which of them were involved more effectively. Here, the students evaluated*

their peers, group friends. While evaluating there, we assigned this form as homework, they evaluated it without seeing other friends, and we told them that we would not show them to other group members.

C2_A4_T: Bu değerlendirme yönteminin çok faydalı olduğunu düşünüyorum çünkü öğrencileri değerlendirirken grup içerisindeki çocukların çalışmalarını biz sadece gözlemliyorduk. Dışarıdan bir gözlem yapıyorduk ama onların hangilerinin daha etkin bir şekilde sürece dahil olduğunu göremiyorduk. Burada öğrenciler akranlarını, grup arkadaşlarını değerlendirdiler. Orada değerlendirirken de eve bunu ödev olarak verdik diğer arkadaşları görmeden değerlendirdiler ve onlara göstermeyeceğimizi bunların bizde kalacağını söyledik.

In addition to the teacher's verbal accounts, only one of the students expressed the activities' *evaluable* aspects. This student talked about one of the evaluation tools, *activity sheet*, during the interview of Activity-2 (*f*=1) in the second cycle. The excerpt of this student presented below implied that the questions prepared to direct the students on the activity sheet were seen as an evaluation tool. This specific finding was also supported by the teachers' explanations about the usability of the activity sheet as an evaluation tool. The expressions of the student and the teacher were as follows:

C2_A2_FG3_S2: I talk to my friend (who did not come to this activity) that the teachers gave us a new paper as usual if he was there in the first activity. We had our exams from there. There were questions; we answered those questions.

C2_A2_FG3_S2: Hocam ben ilk başta hocalar bize her zamanki gibi ilk etkinlikte o (bu etkinliğe gelmeyen arkadaşım) da varsa derim ki her zamanki gibi yeni bir kağıt verdiler. Ondan sınavlarımızı olduk. Sorular vardı hocam o soruları yaptık.

C1_A1_T: The answers were given by our students in the activity sheet can be a criterion for us during the evaluation process. Did they understand the problem? Could they find the causes of the problem? Were they able to find solutions? Could they make the coding part suitable for that solution? All of these can be used as an evaluation criterion.

C1_A1_T: Şimdi burada öğrencilerimizin değerlendirme sürecinde o vermiş olduğumuz kağıtlardaki verdikleri cevaplar bize bir ölçüt olabiliyor. Problemi anladılar mı? Problemin nedenlerini bulabilirler mi? Çözüm yollarını bulabildiler mi? O çözüme uygun kodlama kısmını yapabildiler mi? Bunların hepsi biz bir değerlendirme ölçütü olarak kullanabiliriz.

Practice

The activities such as explainable, purposeful, and evaluable for other peoplewere also found as proper to *practice,* based on the findings. The students had the chance to practise in these activities that required active participation from beginning to the end of the implementation. This *active participation* formed one dimension of the practice during the activities. The active students needed to apply what they knew to complete these activities. *The applicable side* of the practice was handled as the second dimension, based on the data analysis. The frequency distribution of the participants' descriptions concerning these two dimensions was presented in Table 4.40.

Table 4.40 Frequency Distribution of Codes belongs to Category of Practice

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Active participation	3	5 (*n*=3)	1	1 (*n*=1)	2	2 (*n*=2)	1	2 (*n*=2)
	Applicable	9	-	1	-	-	-	-	-
Cycle 2	Active participation	1	-	-	4 (*n*=1)	-	3 (*n*=2)	1	-
	Applicable	-	3 (*n*=3)	-	-	-	2 (*n*=2)	-	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Active Participation

According to the findings in Table 4.40, the teacher described *the active participation* of students in all weeks of the implementation during the first cycle. In detail, he mentioned it most frequently during the interview of Activity-1 (f=3) at the beginning of the implementation. During the second and last week's interview, he expressed only one indicator of the active participation of the students in the activities (f=1). Again, with close numbers, he referred to two of these indicators during the interview of Activity-3 (f=2). In the second cycle, the teacher alluded to the active participation of the students with a lower frequency (f=1) during only two activities conducted at the beginning and end of the cycle (Activity-1 and Activity-4).

As the teacher described, the students participated in these activities actively, and this engaged them in *an active learning process*. In this learning process, they tried to *use the method of discovery* many times. For instance, during the Activity-3, a group of students used two sensors at the same time in their solution. The teacher said that he had not explained this usage in the lesson. However, the students in this group discovered that two condition structures could be used simultaneously in the activities' active learning process. The teacher also stressed the compatibility of the whole activity process with the steps of the discovery method. In this process, the students looked at the problem first, understood it, defined it, and finally developed a product to solve that problem. According to him, these steps were reflecting the steps of the method of discovery learning. During these steps, the students actively participated in the learning process. The teacher maintained that he needed to motivate the students to participate in these process in some specific cases. These cases were mostly experienced at the end of the semesters. He commented on this as follows:

> *C2_A4_T: I was not able to fully capture the attention of the students because of the end of the semester or the lack of stimulus. Then, we included students in active learning, active learning process by giving*

feedback, making corrections, and guiding them at some point in the activity. Hence, they completed their activity by solving the problem.

C2_A4_T: Hem dönem sonu olmasının hem de belki bir uyarıcının olmamasından dolayı çocukların belki dikkatini tam olarak çekemeyebilmişimdir. Daha sonrasında işte bazı noktalarda dönütler vererek düzeltmeler yaparak, rehberlik ederek öğrencileri aktif öğrenmenin içine, aktif öğrenme sürecine dahil ettik. İşte orada o şekilde problemi çözerek derslerini tamamladılar.

Like the teacher's verbal accounts, the frequencies of the student's descriptions were illustrated in Table 4.40. According to findings in this table, *active participation* in activities was described mostly by the students in the first cycle. In this cycle, three interviewed students during the Activity-1 (f=5) expressed the active participation of themselves in activities at the beginning of the implementation. The frequencies of the participants' descriptions in the remaining weeks were very close to each other. Among them, only one student referred to the active participation in the activities during the second activity (f=1). In the remaining weeks' focus group meetings, two students mentioned this active participation with equal frequency (for Activity-3 and Activity-4, f=2). In the second cycle, only one student defined the active participation in these activities during the interview of Activity-2 (f=4). This active participation was also voiced by two students in the third activity (f=2) in this cycle.

Similar to the teachers' expressions about the use of *the discovery method,* one student explained in the focus group meeting that they searched on the internet for what to do during the earthquake to solve the problem during the third activity in the first cycle. As in the use of this method, most of the students emphasized that this active participation was cooperative in the activities. This *active collaborative participation* was also expressed for the programming part of the robots. One of the students commented that this work required active participation, which was *opposite of the course hours,* as they worked with the teacher's instructions as follows:

C1_A1_FG1_S1: This was the first time we programmed the robots by ourselves. Previously, the teacher was telling us then we were doing it. We made it ourselves for the first time.

C1_A1_FG1_S1: İlk defa kendi kendimize robot programlama yaptık. Hoca söylüyordu bize biz yapıyorduk. ilk defa kendimiz yaptık

As collaboration in the programming part, *the division of labor* for the remaining part of the activities was also an illustrator of active participation. This division was not envisaged before the implementation of the first cycle. However, the necessity of the division of labor was explained by several students during the interviews. According to this necessity, if all the group members focused on the same task, other works would not be finished timely during the activities. One of the students commented on this as follows:

C1_A4_FG1_S2: Since we do together, the other task will be left half finished.

C1_A4_FG1_S2: Çünkü hocam ikimiz beraber yaparsak öbür iş yarım kalacak.

Based on the students' descriptions concerning *the division of labor* in the first cycle, it was found that there were three kinds of significant tasks during the activities, and the students made the division of labor based on these task types. These tasks were *filling activity sheets*, *robotic,* and *design tasks.* In the second cycle, the students were asked to do the division of labor in this direction. However, it was also announced to the students that the purpose of the division of labor was only to determine the responsible person and rhe other group members should have assisted this person in the task. It was also emphasized that they could define new labors and made the division based on these tasks. However, the findings indicated that the majority of the groups continued their activities with this distribution of tasks without creating additional tasks. One of the students’ drawings below illustrated the IT laboratory where the activity was carried out. In this drawing (Figure 4-20), the student expressed *the division of labor* as follows:

C2_A2_D_S6:

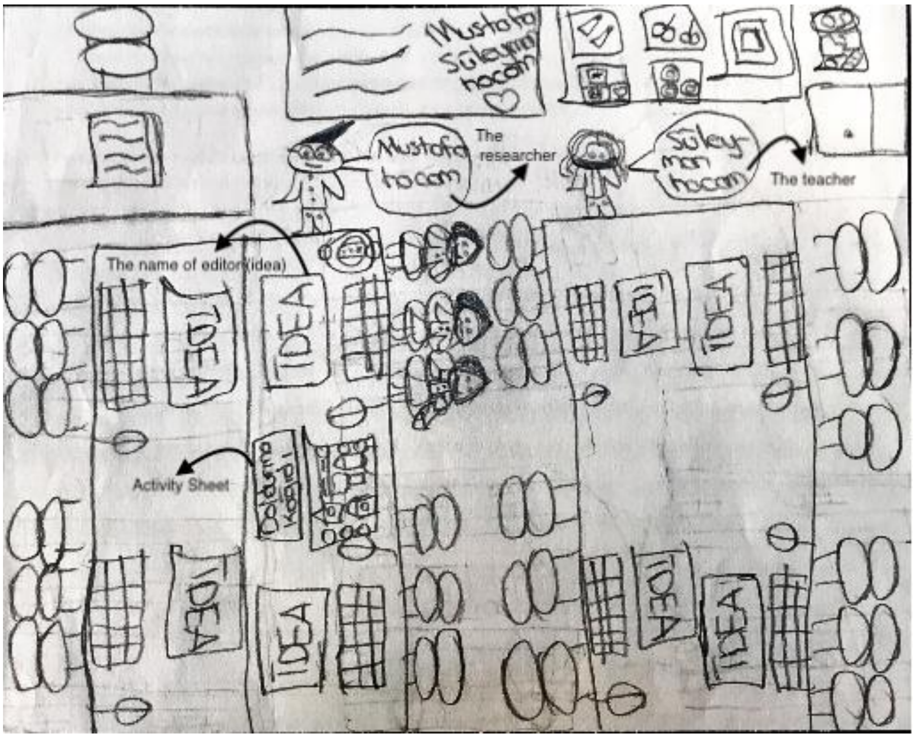

Figure 4-20 Drawing of S6

S6: "I drew the following in this picture: We made the paper at the break time as we filled the paper in the classroom. Here I drew the IT class. I drew my teachers and my group. I drew the teacher's desk, board, computers, materials, and most importantly, I drew my work and the robot. Since I wasa paper filling duty holder, I drew myself in the picture as I was filling the paper by taking everyone's thoughts in the group. One of my friends was programming in the Idea in the picture. The other one was looking at the materials. We did these tasks by helping each other. My classroom friends went to break. We were trying to complete our work here."

S6: "Ben bu resimde şunları çizdim: Biz kağıdı sınıfta doldurduğumuz için teneffüste yaptık. İşte burada bilişim sınıfını çizdim. Hocalarımı, bizi çizdim. Öğretmen masasını çizdim. Tahtayı, bilgisayarları, malzemeleri ve en önemlisi çalışmalarımı ve robotu çizdim. Çizdiğim resimde ben kağıt doldurma görevlisi olduğum için herkesin düşüncelerini alarak kağıdı dolduruyorum. Çizdiğim resimde Arkadaşım A İdea'yı yapıyor. Arkadaşım B'de malzemelere bakıyor. Biz birbirimize yardım ederek bu görevleri yapıyoruz. Diğer arkadaşlarım da teneffüse çıktı. Bir de biz burada çalışmamızı tamamlıyoruz."

The supporting text of S6 implied that *the division of labor* was just set in the groups by taking on the responsibility of the task instead of the assignment of the whole work to that person. The observations during the activities also supported this finding. Moreover, this was also noted in the activity rules announced at the beginning of the second cycle, and students were warned about it. However, some negative expressions in student reflections showed the presence of opposite cases. In those cases, it was understood that in some groups, the students did not act according to the division of labor, and they performed their groupmates' duties. One of those explanations was as follows:

C2_A2_R_S2: What I don't like is that they did everything in it. This activity was not difficult for me because I did not do much. The good aspect was that I also answered the activity sheet and the bad thing is that they did all the things in the activity.

C2_A2_R_ S2: Hoşuma gitmeyenler hepsini onların yapması. Bu etkinlik beni zorlamadı çünkü ben çok şey yapmadım. İyi yönleri etkinlik kağıdını ben de cevapladım ve yazdılar kötü yönü ise hepsini onların yapması.

Applicable

As opposed to the excerpt of S2, when the duties shared appropriately and done collaboratively, the activities allowed the students to practise the information they had got in the courses. This *applicable aspect* as an instructional feature was expressed by the teacher mostly during the interview of Activity-1 (*f*=9) at the beginning of the implementation. He repeated his discourses in this direction once more in the second activity (*f*=1) in this cycle. He did not report the applicable aspect of the activities during the interview of remaining activities in this cycle, as well as all the activities in the second cycle, based on the data provided in Table 4.40.

According to the teacher, the students could apply what they learned in related *subjects in IT* and *science courses* with the activities. They were finding the opportunity to assess themselves on programming by practising in these activities. More specifically, they could *see the results of the algorithms* they created by applying here, and they also monitored whether they performed it correctly or not. Additionally, the activities allowed the students to apply their knowledge in the science course. They could remember the subject taught in science course by applying them in these activities. He expressed this effect as follows:

> *C1_A1_T: We recalled that subject in science course in this activity by applying. They also used the information learned on the subject in the process of the activity.*

> *C1_A1_T: Biz bu etkinlikte fen bilgisi dersinde ki o konuyu uygulayarak hatırlattık. Hem de o konuda öğrenmiş olduğu bilgileri de bu etkinlikte süreç içerisinde kullanmış oldu.*

This feature of the activities, *being applicable,* was also expressed by the students with close descriptions of the teacher. According to data in Table 4.40, they described this aspect of the activities during the interview of Activity-1 (*f*=3) and Activity-3 (*f*=2) in the second cycle of the implementation. In these focus group meetings, the students reported that they had the chance to practise what they learned in the IT course with these activities. Additionally, the students expressed that *they understood these subjects better* by applying in the activities. This better understanding was also prevailing in the related topics in the IT course. One of the students commented on this as in the following:

C2_A3_FG3_S3: Since we can apply what we have learned in that lesson here, we can understand here a little more because we can apply it here. We memorized it more here.

C2_A3_FG3_S3: Hocam o derste öğrendiklerimizi burada uyguladığımız için burada uygulayabildiğimiz için burada biraz daha çok anlayabiliyoruz. Biraz daha yerleşiyor.

Teacher Role

The activities also assigned specific roles to the teacher, which were consideredan important instructional characteristic for the implementation of the activities. Based on the findings of the current study in Table 4.41, it was possible to divide the teacher's role into two main titles:*being active* and *inactive*, according to the descriptions concerning his own role in the activities.

Table 4.41 Frequency Distribution of Codes belongs to Category of Teacher Role

	Codes/**Participants**	**Activity 1**		**Activity 2**		**Activity 3**		**Activity 4**	
		T	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Active	16	-	6	-	1	-	1	-
	Inactive	1	-	-	-	2	-	-	-
Cycle 2	Active	1	-	1	-	1	-	1	-
	Inactive	-	-	-	-	-	-	-	-

Being Active

Role of the teacher was reported by only the teacher during the data collection process. The findings provided in Table 4.41 indicated that he described his role as active during the interviews of all activities in both cycles. He expressed the majority of his descriptions about this type of role at the beginning of the implementation. In detail, the frequency of his descriptions during the interview of Activity-1 (*f*=16) and Activity-2 (*f*=6) was quite high in the first cyclewhereas they were lower than and equal to each other for the remaining activities in both cycles (*f*=1). His descriptions about his role as inactive were quite lower in comparison to descriptions on being active. He described himself as inactive during the activities during the interview of the first (f=1) and the third activity (f=2). His remarkes concerning these two roles were detailed below.

Teacher's *active role* required him of being *the resource of the information* during the activities. As a resource of the information, the teacher utilized two instructional methods to transfer it to the students. *The presentation method* was used to summarize the activity process to the students at the beginning of the implementation in both cycles. Additionally, he was usually active with this method to describe the problem at the beginning of the activities throughout the implementation process. After the students started the activity, the teacher, who stopped using this method, referred to the use of it for a few times during the activity to remind the students of the pieces of the robot using this method.

> *C1_A2_T: Some of them forgot the sensors or their usage because I think there was a situation where the whole class did not involve in the practice with the sensors during the lesson. Therefore, there were situations where I explained the subject to the children as our lecture, I repeated in the activity.*

> *C1_A2_T: Algılayıcılarla ders esnasında uygulama sırasında belki tüm sınıf haşir neşir olma durumu olamadığı için bazıları algılayıcıları unutmuşlar ya da kullanım şekillerini unutmuşlar. Yani etkinlik içerisinde ders anlatım noktasında da çocuklara konuyu da anlattığım durumlar oldu, tekrar ettiğim.*

Apart from the presentation method as the source of information, *mentoring* also appeared as a teaching role that he involved in the process of the activity by guiding the students when needed. In the activities, the teacher generally performed this role by asking students various questions to *control their work* and *giving feedback* to the students' questions to guide them in the process. The teacher reported that this level of guidance was not consistently the same in the process. According to him, the guidance needed by the students was *decreasing as the activities progressed*. He expressed this as follows:

> *C2_A4_T: I will say the same thing again, but mostly I was in the position of mentor. It was a position to direct the students, and this direction gradually decreased. Just like a working machine, it was decreased towards the second and third activity.*

> *C2_A4_T: Daha çok yine aynı şeyi söyleyeceğim ama ben rehber pozisyonunda oldum. Çocukları yönlendiren konumunda ve gittikçe bu yönlendirme daha da azaldı. Tıpkı bir işleyen makine gibi ikinci ve üçüncü etkinlikte artık ona doğru ilerledi.*

In this mentoring process, the students asked him several questions in various phases of the activities. The common point of these questions was that *they saw the teacher as a source of information*. The teacher expressed that he encouraged the students to ask any kind of questions.

> *C1_A1_T: I told them that that they should never have hesitated to ask questions. I alsotold them that therewas no simple question so they should not have thought it as a simple question.*

> *C1_A1_T: Soru sorarken de hiçbir zaman çekinmemeleri gerektiğini basit bir soru olmaz, basit bir soru gibi düşün memeleri gerektiğini söylüyordum.*

Being Inactive

In contrast to being active, the teacher also expressed that he did not take over any role in some parts of the activities. In these inactive phases, he only *observed the students* in certain parts of the activities. The teacher, who said that these parts were mostly in the production phase, expressed this situation as in the following:

> *C1_A3_T: In other parts, I have never been in a position to explain the topic or guide the students. I just observed them.*

C1_A3_T: Diğer kısımlarda herhangi bir şekilde ne konu anlatan, ne de rehber pozisyonunda bulundum. Sadece onları gözlemledim.

Contributions

The contributions of activities to the students and the teacher were also considered as one of the characteristics of these activities. The results about these contributions were reported in this part of the study as two different themes namely *the contributions to learner* and *contributions to the teacher*. The contributions of the activities to the students were categorized as *skill development*, *learning outcomes*, and *motivation,* based on the data analysis. The theme and the related categories were illustrated in Figure 4-21.

Contributions to Learner

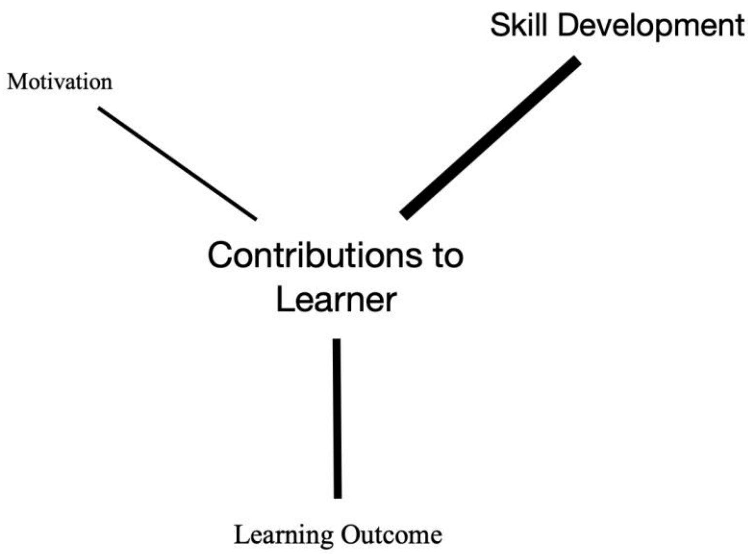

Figure 4-21 Categories of Contributions to Learners

The categories of the theme and the related codes were given in Table 4.42. In this table, a code tree for the categories of the contributions to learner theme listed from the most cited to the least one during the interviews with the participants. Each category and the related codes were elaborated on one by one after this illustration.

Table 4.42 The Code Tree of Contributions to Learner Theme

Categories/Codes	Σf
Skill Development	**186**
Soft	102
CT	39
ICT	31
Design	14
Learning Outcome	**86**
IT	41
Science	40
Other courses	5
Motivation	**32**
Interest	24
Success feeling	8

Skill Development

The development of skills emerged as one of the contributions of activities to the students, based on the data gathered from the participants. In detail, both the teacher and the students reported that the activities contributed to the students’ skills supporting them in both social and educational life. The skill sets embedded in those areas of life were cumulated into four headings that began with *soft skills* associated with students' non-technical skills. The findings also indicated that the activities contributed to students' *computational thinking skills* throughout the implementation process. The participants also pointed out that the activities helped the students to acquire technical skills, specifically *ICT (Information and Communication Technology) skills* and *design skills.* The frequency distribution of descriptions of the participants for all these skill sets was illustrated in Table 4.43.

Table 4.43 Frequency Distribution of Codes belongs to Category of Skill Development

	Codes/**Participants**	**Activity 1** **T**	**S**	**Activity 2** **T**	**S**	**Activity 3** **T**	**S**	**Activity 4** **T**	**S**
Cycle 1	Soft	2	-	1	6 (*n*=3)	5	14 (*n*=4)	3	8 (*n*=2)
	CT	11	2 (*n*=1)	5	2 (*n*=2)	5	3 (*n*=2)	3	-
	ICT	3	2 (*n*=2)	3	4 (*n*=3)	4	2 (*n*=2)	1	-
	Design	3	-	-	-	-	-	-	1 (*n*=1)
Cycle 2	Soft	9	3 (*n*=2)	2	4 (*n*=3)	2	25 (*n*=11)	8	10 (*n*=6)
	CT	-	2 (*n*=2)	-	2 (*n*=1)	-	-	4	-
	ICT	-	4 (*n*=2)	-	3 (*n*=3)	1	1 (*n*=1)	2	-
	Design	-	-	-	9 (*n*=4)	-	1 (*n*=1)	-	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

Soft Skills

According to the findings provided in Table 4.43, the teacher reported the *development of soft skills* of students during the interviews of all activities throughout the implementation process in both cycles. In detail, he described the improvement of these skills of students at the beginning of the first cycle during the interview of Activity-1 (*f*=2). His descriptions continued for the remaining activities in this cycle, and the frequency of them was quite high for the interview of Activity-3 (*f*=5) in this cycle. Moreover, the teacher defined students' soft skills as developed, depending upon the activities during the second cycle of the implementation. In this cycle, the findings indicated that the majority of his descriptions belonged to Activity-1 (*f*=9) and Activity-4 (*f*=8). The findings also indicated that he expressed this development in equal frequencies in the remaining two activities (*f*=2).

According to the teacher's descriptions, the activities contributed to *the students' soft skills* during the implementation process. Some of the students gained new insights such as *helpfulness* and *respect for others* with these activities. Therefore, they were very useful for *the education of values.* Among those values, *the awareness of disabled people's life* was the most remarkable one. The students saw that they could help these people by using technology within the third activity scope. In this and other activities, intra-group and inter-group interaction enabled the students to form *better friendships* and contributed positively to their other soft skills, *communication*. The students with improved communication skills were able to express themselves in a working group environment, and they felt *self-confident* in those collaboration process. The teacher pointed out the improvement of these skills during the interview of the last activity of the implementation process as follows:

> *C2_A4_T: I also think that they have increased self-confidence with these activities. I think they can express themselves better.*

> *C2_A4_T: Bir de bu etkinliklerle kendilerine güvenlerinin arttığını düşünüyorum. Kendilerini daha iyi ifade edebildiklerini düşünüyorum.*

The students also commented on the development of their *soft skills* with the expressions closer to the teacher's during the focus group interviews. According to them, *the sense of sharing* was improved with the collaboration in the activities. These shares led to conclusions such as the end of some insults between the students and resulted in *effective communication* in the classroom. Additional soft skills developments related to the activity's scope were also in the form of *increasing awareness* for both the environment and the disabled people. A student claimed that these activities were beneficial in terms of increasing awareness for the disabled by saying follows:

> *C2_A3_FG1_S1: Actually, I had never thought that disabled people could suffer from natural disasters before, but I started to think about it after this activity.*

> *C2_A3_FG1_S1: Aslında ben daha önce hiç engellilerin doğal afetler sırasında zarar görebileceklerini düşünmemiştim ama bu konuda sonra düşünmeye başladım.*

The findings provided in Table 4.43 indicated that the students did not report the contribution of activities to their *soft skills* at the beginning of the first cycle of the implementation. However, they expressed this progress during the focus group meetings in all other remaining activities throughout the implementation process. In detail, four students in the focus group interviews of the third-week activity described the contribution of the activities to their soft skills more frequently (*f*=14) than other week activities including Activity-2 (*f*=6) and Activity-4 (*f*=8) in the first cycle. Similarly, in the second cycle, the majority of the students' descriptions concerning the improvements of the soft skills belonged to 11 students in the group meeting of the same activity in the first cycle (*f*=25). The difference of this cycle from the first cycle was that two students in the focus group meeting of the first activity also had expressions about the development of these soft skills as well as other activities.

To sum up, *the development of soft skills* as a contribution of activities for the students was mentioned both by the teacher and the students during the data collection process. These soft skills were mostly towards students' own development. They increased the sensitivity of students on several topics, which resulted in the rise of awareness of values on those topics. The participants also said that these activities contributed to students' communication and collaborative skills which were other soft skill developments with the activities.

CT Skills

According to the data in Table 4.43, one of the activities' contributions was on *CT (Computational Thinking) skills* of students. According to the participants, since students experienced problem-solving steps during these activities, they specifically contributed to the students' *problem-solving skills* among the CT skills. While solving these problems, the students were in *an autonomous learning process* where they learned from their mistakes. During the programming phase, the students who learned by debugging the errors also improved their *algorithmic thinking skills* among the CT skills.

The students referred to the *improvement of CT skills* after most of the activities during the implementation process. According to the findings presented in Table

4.43, the students started to report that the activities affected their CT skills mostly at the early activities in the implementation process of both cycles. Firstly, one of the students expressed it during the focus group meeting of the first activity (*f*=2) in the first cycle. Similarly, two students expressed that they developed themselves in problem-solving and creating the algorithm in the second activity (*f*=2). In this cycle of the implementation, two students claimedthat they had forgotten the creation of a flowchart before this activity. However, they put forward that they remembered it and completed their deficiencies in creating flowcharts with the activity in the third week of the implementation (*f*=3). In the second cycle, the students expressed that the activities improved themselves in problem-solving since they felt they were able to solve problems better after these activities. These expressions about improvement on problem-solving belonged to the interviewed students at the end of the first (*f*=2) and second activity in this cycle. One of these students expressed this contribution as in the following:

> *C1_A1_FG1_S2: When we encounter problems in the future, we can find solutions. It made it much easier for us to find alternative solutions.*
>
> *C1_A1_FG1_S2: İleride sorunlarla karşılaştığımızda çözüm yolları bulabiliriz. Alternatif çözüm yolları bulmamızı baya kolaylaştırdı.*

The teacher also discussed that the activities improved *the problem-solving skills* of the students during the data collection process of several activities. At the beginning of the implementation, he referred to it during the interview of the first activity as in the following:

> *C1_A1_T: I think their problem-solving skills have increased because they have found out their causes and solutions. So I think it increased in a positive direction.*
>
> *C1_A1_T: Problem çözme becerilerinin arttığını düşünüyorum çünkü nedenlerini, çözüm yollarını kendileri buldular hani arttırdığını düşünüyorum. Olumlu olarak bu şekilde.*

The teacher alluded to the development of *other CT skills* of the students most frequently at the beginning of the implementation as mentioned in the excerpt about problem-solving above. In detail, the majority of his descriptions on the contribution of the activities to the students' CT skills belonged to the first activity (*f*=11) in the first cycle, based on the findings in Table 4.43. Discourses of him in this direction continued throughout all activities in this cycle. However, in the second cycle, he referred to this contribution during only the last activity (*f*=4). In one of his description after this activity, he commented on the development of the *algorithmic thinking skills* of the students via the activities.

> *C2_A4_T: We concretely observed that the students' algorithmic thinking skills improved.*

> *C2_A4_T: Algoritmik düşünme becerilerinin arttırdığını somut bir şekilde gözlemledik.*

ICT Skills

According to the responses of the participants during the interviews, *ICT (Information and Communication Technology) skills* were the other skill development area as an outcome of activities. The findings presented in Table 4.43 indicated that there were two aspects of the improvement of ICT skills. One of these aspects, *the robotic skills* of students, were reported as improved during the implementation process both by the students and the teacher. The teacher did not mentioned the development of this skill at the beginning of the implementation and the entire process of the second cycle. In contrast, in the first cycle, he reported the development of students' robotic skills during the interview of Activity-2 (*f*=2), Activity-3 (*f*=3), and Activity-4 (*f*=1).

According to the teacher, the students developed *programming skills* better via these activities. For instance, some students learned to use some programming structures in the activities even though they were not covered in the course. Using two structures simultaneously was one of these contributions based on his observations.

Moreover, the students improved *the skill of using robots,* especially some pieces of them such as sensors and voice cards, as the contribution of these activities. In one of the interviews, he explained the use of the sound card, which could not be covered very well in the course hours, as follows:

> *C1_A2_T: The voice card was the last piece of the robot I covered in the course hours. We did not have much opportunity to practise there. Indeed, I could not make an implementation with the voice card that all the students attended in the classroom. At that point, the children got the help on where to connect the sound card. They said they wanted to do it. They got help from me at points like where to connect and how to do it. So, in this activity, our students used sound sensors as extra sensors and extra robot pieces. As I said, they never used it in the previous one. The groups that used it also learned its usage.*

> *C1_A2_T: Ses kartı bizim en son, benim derste gösterdiğim en son robot parçasıydı. Çok fazla uygulama yapma fırsatımız olmamıştı. İşte ses kartlarını tüm sınıfta hani öğrencilerin etkinlik yaptığı bir uygulama yapamamıştım. O noktada çocuklar hani ses kartını nereye bağlayacaklarını yardım alarak yaptılar. Hani yapmak istediklerini söylediler hani nereye bağlayacak, nasıl yapacağız gibi noktalrada benden yardım aldılar. Yani bu etkinlikte öğrencilerimizin ekstra algılayıcılar ve ekstra robot parçası olarak ses kartını kullandılar. Dediğim gibi bir öncekinde hiç kullanmamışlardı ve onun kullanımını da o kullanan gruplar öğrenmiş oldular.*

The students also referred to the contribution of activities on the use of the voice card during the focus group meetings. Additionally, it was also expressed by several students that there were contributions regarding *the installation of robots*. In fact, the students were getting the robots ready during the course hours. They encountered the case that they got all parts separated from each other and installed their robots for first time during the first activities in both cycles. Therefore, some students reported that they gained the knowledge as to how and where these parts should have been connected during the interviews in those early activities. In addition to the use of robotic pieces, the contributions of the activities in *programming* were also reported by the students. One of them explained the contribution of the activities in the *use of the editor* to program the robots during the activities as follows:

> *C1_A2_FG2_S2: For example, we did not know how robots were designed and how they were programmed in the Idea software. We learnt them.*

> *C1_A2_FG2_S2: Şey mesela idea programında robotların nasıl tasarlandığını, nasıl yapıldığını bilmiyorduk. Onları öğrendik.*

According to the findings presented in Table 4.43, the students expressed the contribution of the activities for robotic among ICT skills during the data collection process of all activities except the last activities in both cycles. Among these activities, three students during the focus group interview of Activity-3 described these skills as improved more frequently (*f*=4) than other activities in the first cycle. Similarly, two students stated that the activities contributed to their *robotic skills* more frequently during the interview of the first activity (*f*=4) in the second cycle.

In addition to robotic developments as one of the ICT skills, *the media use* as a contribution for the students was reported only by the teacher, based on the data provided in Table 4.43. In detail, the teacher only mentioned this contribution in the data collection process of the three activities during the implementation. The first one was during the activity at the beginning of the first cycle of the implementation (*f*=3). Then, he repeated discourse on this contribution of activities on the use of media during the second activity in the same cycle. Lastly, he referred to them during the interview of the last activity in the second cycle (*f*=2) where the implementation was completed.

> *C1_A2_T: Students were using the computer in these activities. They were using the idea program they have just seen in the course hours. There is progress in their use of information and technologies since they get in touch*

with them more here. They have already advanced on this issue from the beginning of the year. We can say that the activities have a positive contribution.

C1_A2_T: Çocuklar hani bilgisayarı kullanıyorlar, yeni görmüş oldukları idea programını kullanıyorlar. Bilgi ve teknolojileri kullanma noktasında daha fazla bunlarla haşir neşir oldukları için bir ilerleme söz konusu. Yani sene başından zaten çok çok ilerdeler, böyle bir şey söz konusu. Etkinliklerin olumlu yönde katkısı var diyebiliriz.

In summary, the study participants mentioned the positive effects of these activities on the students' ICT skills. *The use of pieces of robots*, *the construction of robots*, and *programming of robots* were those endowed ICT skills related to robotic, according to the findings. Additionally, contributions to various *media usage* such as internet and computer were other ICT skills.

Design Skills

The participants' expressions on the activities' contributions indicated that the last skill improvements of students were about the design. According to them, the students' *design skills* improved during the activities since all the students experienced a production phase during the activities, and they needed to use *hand skills* too much during that experience. The students mostly got better in *design* and *art* with these experiences. One of those experiences in the first activity was expressed by the teacher as contributed to the design skills of the students, according to the findings in Table 4.43. He commented on design skills during only this activity (*f*=3) throughout the implementation process in both cycles. One of his comments in this activity about the students' development of hand skills was in the following:

C1_A1_T: I think that it affected us positively in those areas. In particular, I think that it was positive in developing hand skills of the students by using these auxiliary materials.

C1_A1_T: O alanlarda hani olumlu yönde bizi etkilediğini düşünüyorum. Özellikle çocukların bu yardımcı malzemeleri kullanarak el becerilerinin gelişmesi noktasında olumlu olduğunu düşünüyorum.

The students also commented on their improvements in design during the interviews of several activities. Based on the findings provided in Table 4.43, only one student expressed this improvement in the first cycle. Specifically, this student reported that their *drawings* were improved thanks to the activities. The remaining expressions of the students were gathered during the data collection process of the second cycle. The majority of these expressions belonged to four interviewed students at the end of the second activity (f=9). Additionally, only one student expressed he/she learned to design in these activities with the teacher's help.

C2_A3_FG3_S1: The contributions of the activities in the IT course have been quite a lot for us. For example, I did not know how to design. I learned to design with the help of the teacher here.

C2_A3_FG3_S1: Hocam bilişim dersindeki etkinliklerin bize katkıları baya oldu hocam. Mesela ben tasarlamayı bilmiyordum hocam. Hocadan yardım alarak tasarlamayı öğrendim.

Learning Outcome

In addition to skill development, *learning outcomes* at the cognitive level were also found to be the contribution of the activities to the students. According to findings, these learning contributions were in the form of *new learnings* in some cases and the *improvement of previous learnings* in other cases. In detail, several students revealed that they learned new things during the activities. The improvement of previous learnings occurred in two ways. In one of them, the students had the chance to corroborate with their previous learnings while, in another, they corrected the misconceptions in their previous learnings. Both new learnings or the improvement of previous learnings and the learning outcomes of the activities were clustered under different fields such as *IT (Instructional Technology), science,* and *other courses* in the data set. The frequency distribution of the participants' expressions concerning these learning outcome fields was presented in Table 4.44.

Table 4.44 Frequency Distribution of Codes belongs to Category of Learning Outcome

	Codes/**Participants**	**Activity 1**		**Activity 2**		**Activity 3**		**Activity 4**	
		T	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	IT	2	4 (*n*=2)	3	6 (*n*=4)	1	6 (*n*=4)	-	-
	Science	3	2 (*n*=1)	4	10 (*n*=3)	-	4 (*n*=3)	-	-
	Other courses	-	2 (*n*=1)	1	1 (*n*=1)	-	-	-	1 (*n*=1)
Cycle 2	IT	1	8 (*n*=4)	1	5 (*n*=3)	1	2 (*n*=2)	3	-
	Science	-	8 (*n*=5)	-	4 (*n*=4)	-	4 (*n*=4)	1	-
	Other courses	-	-	-	-	-	-	-	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

IT Outcomes

According to the findings in Table 4.44, the first field of learning outcomes of the activities was the *IT course.* The teacher talked about the contribution of the activities in this area throughout almost the whole process of the implementation. In detail, the teacher started to referred to the learning outcomes in the IT course in the first activity (*f*=2) and expressed it in all other weeks except for the last activity in the first cycle. The majority of his descriptions concerning the contribution of the activities in the IT course belonged to the interview of the second activity (*f*=3) in this cycle. In the second cycle, it was seen that the teacher mentioned the contributions in this area during the interview of all activities. He alluded to these contributions more frequently during the interview of Activity-3 (*f*=3) than other activities in this cycle.

The teacher reported one of the contributions in *the IT course* that the students were able to know the reason for the creation of an algorithm with these activities. They were knowledgeable about creating algorithms before these activities, but they realized why they did it through these activities. Thus, they learned the importance of the *subject of the algorithm* better in this way. With these, the activities became complementary parts to the learnings in the IT course. Additionally, the activities were effective in reaching at *the objectives of the course*. In detail, since the objectives of the course about *the problem solving* and *algorithm subjects* were related to the activities, the students' competencies in those objectives were improved as a result of the implementation. He expressed this as in the following:

> *C1_A3_T: Of course, as the students did, they succeed in and learned from these activities, their competencies in the objectives of the information technology course increased.*
>
> *C1_A3_T: Tabi yaptıkça, başardıkça da zaten hani öğrendikçe de bilişim teknolojileri dersindeki kazanımlardaki o yeterlilikleri de artmış oluyor.*

The activities' contribution to the learning outcome of the IT course was also expressed by the students. First of all, this was on *a change of perception concerning the robots,* according to the responses given by the students. For instance, since the robots were given to the students as full-kit before the activities, and they used structurally different during the activities, the perception of the students changed about *the structure of the robots*. Students who said that they learned that robots could be without wheels were an example of this situation. This was also reflected in the drawings of the students. In the first activities, while the students were usually drawing the robots in the same structure they owned, they mostly drew in different structures in the following activities. One of those drawing (Figure 4-22) in which the robot was drawn as a *humanoid robot* given by one of the students after the fourth activity was the following:

C2_A4_D_S5:

Figure 4-22 Drawing of S5 for Activity-4

Like the robots' structural perceptions, the activities contributed to the change in students' thoughts about their *usage areas*. This perception change was mostly related to the ill-structured problems in the activities. For instance, several students expressed that they learned that *people with disabilities could be helped with robots* after the third activity.

The students also reported that they improved themselves in *programming* with these activities. There were several findings regarding *the use of the editor* in which students programmed the robots. Some of the students expressed that they learned *the menus in the editor* with these activities. Since they drew the flowcharts during the programming the robots both in editor and on the activity sheets, the activities also contributed to the students on *the subject of the algorithm*. This learning was sometimes in the form of correction of old misconception while sometimes in the form of acquiring completely new information. For instance, two students who were confused about *the functions of the shapes used in flowcharts* put forward that these confusions were resolved as a result of the activities. Additionally, one of the students explained how they learned *the usage of loop structure* when creating a flowchart during the third activity as follows:

> *C1_A3_FG3_S1: We had put an end to our flowchart, but it would do it once and never do it again. But if we tied it to the beginning, it would do it continuously. We learned this.*

> *C1_A3_FG3_S1: Biz en sona bitir koymuştuk ama onu bir kez yapacaktı ve bir daha yapmayacaktı. Ama onu başa bağlasaydık sürekli yapcaktı. Sürekli olunca. Bunu öğrenmiş olduk.*

The findings related to the contributions of activities on algorithm also coincided with the results of the quizzes applied to students both before and after the implementation of the activities. In fact, unplugged algorithm quiz contained open-ended questions that were given to the students in both cycles two times: before the activities and at the time when the activities ended. The answers given by the students in these quizzes were evaluated with the help of a rubric. Detailed information on the development and implementation of the test and rubric was presented in the methodology chapter of the study. As indicated in that section, the normality of the distribution of the unplugged algorithm test scores was not met. Therefore, a non-parametric test was conducted to examine the change of the students' scores before and after the implementation process in both cycles. The descriptive statistics of students for these tests (please see in Table 4.45) and the findings of the test for related samples (please see in Table 4.46) were presented in the following.

Table 4.45 Descriptive Statistics for Unplugged Algorithm Scores of the Students

Cycle	Test	N	M	SD	Min.	Max.
1	Before	24	80.70	15.85	37.50	99.00
	After	7	87.86	13.08	62.00	100.00
2	Before	49	63.66	20.63	15.00	93.50
	After	33	68.07	20.79	0.00	92.00

The descriptive statistics for the students' scores on the unplugged algorithm quiz in Table 4.45 indicated that there were 24 students who took the quiz before the implementation process in the first cycle. However, only seven of them completed the same quiz after five weeks at the end of the activities. The scores of the students were ranged from 37.50 to 99 (*M*=80.70, *SD*=15.85) at the beginning of the implementation process whereas they were ranged from 62 to 100 (*M*=87.86, *SD*=13.08) at the end of the implementation in this cycle. In the second cycle, 49 students took the quiz one week before the beginning of the activities. After eight weeks, 33 students completed it again. The scores of the students were between 15 and 93.50 (*M*=63.66, *SD*=68.07) at the beginning of the activities. On the other hand, they were ranged from 0 to 92 (*M*=68.07, *SD*=20.79) at the end of the implementation process.

As normality of differences between the two scores assumption was not satisfied, one of the non-parametric tests, Wilcoxon Signed Rank Test, was performed in order to examine whether there was a significant difference on unplugged algorithm quiz scores of students. The results of the tests for both cycles were presented in Table 4.46.

The results of the Wilcoxon Signed Rank Test in Table 4.46 indicated that the scores of the students on the unplugged algorithm quiz were significiently increased throughout the implementation process in the second cycle ($z=-2.54$, $p<.05$). The sum of the ranks in favor of after the implementation scores was 294.50 while the sum of the ranks in favor of before the implementation scores was 83.50 in this cycle.

However, this increase was not a significant for the students in the first cycle. The potential reasons for the results of this difference between these two cycles were elaborated on in the discussion chapter.

Table 4.46 Wilcoxon Signed Ranks Test Results on Unplugged Algorithm Quiz Scores

Cycle	Unplugged Algorithm Quiz	N	Mean Rank	Sum of Ranks	z	p
1	Negative Ranks	2	5.00	10.00	-0.68	.50
	Positive Ranks	5	3.60	18.00		
	Ties	-				
2	Negative Ranks	6	13.92	83.50	-2.54	.01*
	Positive Ranks	21	14.02	294.50		
	Ties	-				

* p< .05

Science Course Outcomes

According to the interviewed participants, another learning outcome of the activities belonged to *the science course*. The findings provided in Table 4.44 indicated that the teacher mostly expressed the contribution of the activities to the outcome of the Science Course at the beginning of the implementation process. In fact, he described some of these outcomes during the interview of Activity-1 (f=3) in the first cycle firstly. Then, his descriptions reached the highest point in terms of the frequency during the interview of the second activity (f=4) in this cycle. In addition to these descriptions at the beginning of the implementation, he expressed this contribution at the end of the implementation last time during the interview of Activity-4 (f=1) in the second cycle.

The teacher mostly expressed the overall learning contribution of the activities to *the Science Course*. According to him, the students had *the opportunity to experiment* with the subject they studied in the science course with the first activity. They *recalled their knowledge in the Science Course* by using it in those experiments or by practising related knowledge in other activities. In addition, the students *acquired new information about this course* during the activities. They mostly obtained the new information *from the video* viewed at the beginning of the activity and *the problem scenarios* presented in the activity sheet. He discolosed his observation about the contribution of the problem scenario on the learning outcome of science course as in the following:

> *C1_A2_T: I have observed that the students also got new information from the problem statement. For example, we had students who did not think that sun rays could be harmful. These students always thought it was useful. We had students who did not know that the sun involved vitamin D and did not know that it was so useful. The problem statement also taught them new information about science course.*

> *C1_A2_T: O problem durumundan çocukların yeni bilgiler de edindiklerini gözlemledim. Hani mesela güneş ışınlarının zararlı olabileceğini hani düşünmeyen öğrencilerimiz de vardı. Hep faydalı olduğunu düşünen öğrenciler. Ya da d vitamini falan olduğunu bilmeyen bu kadar faydalı olduğunu da bilmeyen öğrencilerimiz de vardı, hani problem durumu yeni bilgiler de öğretmiş oldu. Fen bilgisi ile ilgili.*

The excerpt from the teacher overlapped with the description of one student who stated that he/she learned the information about *vitamin D from the text of the problem scenario* of this activity. Similar to this expression, the students reported that the activities contributed to several subjects in the science course i.e., *heat and light, disruptive natural events,* and *force and friction subjects*. It was clear from this finding that all of these subjects were the topics of the science course which were used when forming problem scenarios of the activities before the implementation. However, some of the students also mentioned that these activities were effective for learning other subjects related to the science course apart from the subjects related to the problem scenarios. *The stage of the matter* was one of those subjects, and one of the students expressed this subject as the learning outcome of the Activity-2.

C1_A2_FG3_S1: We learned that salt melts ice. Our teacher brought this to our mind. In fact, he said the robot could stand there and pour salt. Then it came to our mind.

C1_A2_FG3_S1: Tuz buzu eritiyor onu öğrendik. Bunu aklımıza hocamız getirdi. Aslında orada durup tuz dökebilir demişti. Ondan sonra aklımıza geldi.

The findings in Table 4.44 indicated that the students expressed the learning outcomes of activities in the science course during the interviews of all the activities except for the last activities in both cycles. In detail, one interviewed student described this outcome during Activity-1 firstly (f=2). The majority of the students' descriptions of the science course learning outcome of the activities belonged to the next week's activity (f=10) in the first cycle. Three interviewed students expressed the science course learning outcomes for the activities during the interview of Activity-3 (f=4) last time in this cycle. In the second cycle, five students who participated in the first activity referred to these outcomes more frequently (f=8) than four students interviewed during the second (f=4), and the other four students participated in the focus group meeting of Activity-3 (f=4).

An academic achievement test was also applied to examine the learning outcomes in the science course. This academic achievement test involved multiple-choice questions about the related science course subjects to the activities. The test was given to the students before the activities, and they completed the same test again after the implementation. The development process and reliability analysis of the Science Academic Achievement Test were presented in the methodology chapter of the study. The descriptive statistics for this test when it was applied in both cycles were provided in Table 4.47.

Table 4.47 Descriptive Statistics for Science Academic Achievement Test Scores of the Students

Cycle	Test	N	M	SD	Min.	Max.
1	Before	23	65.22	15.49	38.10	95.24
	After	14	71.09	15.68	33.33	90.48
2	Before	46	56.21	18.20	9.52	90.48
	After	17	65.94	14.79	38.10	85.71

According to the descriptive statistics of the students on the Science Achievement Test provided in Table 4.47, a total of 23 students took the test before the implementation process of the activities in the first cycle. The scores of these students were ranged from 38.10 to 95.24 (*M*=65.22, *SD*=15.49), which indicated that the student with the lowest score in this test answered only 8 of the 21 questions correctly while the student with the highest score gave the correct answer to 20 questions among the total 21 questions in the test before the implementation of the activities in the first cycle. After the completion of all the activities, the test was applied again to 14 students in this cycle. The scores of these students were between 33.33 and 90.48. This result indicated that the student with the lowest score in this test answered only 7 questions correctly among a total of 21 questions, and the student with the highest score gave the correct answer to 19 questions in the test when they completed the activities in the first cycle. In the second cycle, 46 students participated in the Science Achievement Test before the implementation process. The scores of the students ranged from 9.52 to 90.48 (*M*=56.21, *SD*=18.20). This result showed that the student with the lowest score in this test had only 2 correct answers among 21 multiple-choice questions while the highest score belonged to the student who answered 19 questions correctly. After eight weeks, a total of 17 students took the same test again at the end of the implementation process. The scores of the students who participated in this test ranged from 38.10 to 85.71 (*M*=65.94, *SD*=14.79). According to this result, the student who had the lowest score in the Science Academic Achievement Test answered only 8 of 21 questions correctly whereas the highest score belonged to the student who had 18 correct answers among 21 total questions.

Since the normality of differences between the scores was not satisfied among the scores in both cycles, one of the non-parametric tests, Wilcoxon Signed Rank Test, was performed in order to examine whether there was a statistically significant change between scores of students. The results of the tests for both cycles were presented in Table 4.48.

Table 4.48 Wilcoxon Signed Ranks Test Results on Science Academic Achievement Scores

Cycle	**Science Achievement**	**N**	**Mean Rank**	**Sum of Ranks**	**z**	**p**
1	Negative Ranks	4	4.88	19.50	-1.21	.23
	Positive Ranks	7	6.64	46.50		
	Ties	1				
2	Negative Ranks	4	4.88	19.50	-2.31	.02*
	Positive Ranks	11	9.14	100.50		
	Ties	1				

* $p < .05$

The results of the Wilcoxon Signed Rank Test provided in Table 4.48 indicated that there was not enough evidence to conclude a significant change in science academic achievement test scores of the students in the first cycle. In contrast, the scores of students after the implementation process were significantly higher than the scores of students that measured before the implementation of activities in the second cycle ($z=-2.31$, $p<.05$). The sum of the ranks in favor of the end of the implementation process was 100.50, whereas it was 19.50 before the implementation process. Therefore, the students' science achievement scores significantly increased during the implementation process of the second cycle. It can be expressed as a result of this analysis that the activities contributed to the academic achievement of the students on related science subjects in the second cycle.

Outcome for Other Courses

In addition to Science and IT Courses, the participants also expressed that the activities contributed to *learning outcomes in other courses*. The fields of these courses were related to *linguistic, art, math,* and *social sciences*. The data provided in Table 4.44 indicated that these areas were reported both by the teacher and the students only in the first cycle of the implementation. The teacher reported one of those fields only during the interview of Activity-2 (*f*=1) in this cycle. The teacher expressed that the activities contributed to the students in the field of art besides IT and science, saying the following:

> *C1_A2_T: The activity has an impact on IT and science. They are already the fields where we use our activity. Apart from that, it also has an impact in the field of design and visual arts.*

> *C1_A2_T: Bilişim teknolojileri, fen bilgisi alanlarında etkisi var. Zaten onlar bizim de etkinliğimizi kullandığımız alanlar. Onun haricinde yine tasarım, görsel sanatlar alanında etkisi var.*

The findings presented in Table 4.44 indicated that the students expressed the contribution of activities for other fields during the interviews of all activities except for Activity-3. During the interviews of these activities, the students reported that the activities contributed to *the linguistic* because they were typing what they decided while filling the activity sheet during the first phase of the activities. Also, such a contribution took place in the field of *math course* since they had to do some calculations during the design and programming parts. Apart from these two-course fields, one of the students stated in the reflection paper that these activities could contribute to *social science course*. This student's reflection was as in the following:

> *C2_A3_R_S4: I think this activity was useful. It especially contributed to our science and social courses. I can use it in every field.*

> *C2_A3_R_S4: Bence bu etkinlik faydalıydı. Özellikle fen ve sosyal dersimize katkısı oldu. Her alanda kullanırım.*

Motivation

Along with skill development and learning outcome, the activities were also effective for the enhancement of *the motivation* of the students. The contribution of the activities was also placed on the increase in *the interest* of the students toward the courses and the activities, according to the participants. Moreover, they engaged the students with the enhancement of their *success feeling*. The frequency distribution of the participants' descriptions of these codes was presented in Table 4.49.

Table 4.49 Frequency Distribution of Codes belongs to Category of Motivation

		Activity 1		**Activity 2**		**Activity 3**		**Activity 4**	
	Codes/**Participants**	**T**	**S**	**T**	**S**	**T**	**S**	**T**	**S**
Cycle 1	Interest	6	-	4	-	3	-	2	-
	Success feeling	-	2 (*n*=2)	-	-	-	-	-	-
Cycle 2	Interest	2	-	2	-	1	-	4	-
	Success feeling	1	1 (*n*=1)	-	1 (*n*=1)	-	1 (*n*=1)	2	-

**n* refers to the number of students responsible for the verbal occurrences within interviews

According to the findings in Table 4.49, only the teacher referred to the contribution of the activities to the increase in students' interest toward the courses and the activities during the data collection process. He specified this contribution for all the activities. The frequency of his description was quite high at the beginning of the implementation. In fact, he mostly reported the enhancement of the interest of students in the early weeks of the implementation (including Activity-1, *f*=6 and Activity-2, *f*=4) in the first cycle. In contrast, the majority of his descriptions in the second cycle belonged to the last activity (*f*=4) in the second cycle.

The teacher expressed that the activities increased *the students' interest* for both *IT* and *science courses*. According to him, the students performed in these activities without getting bored. Thus, the activities with this entertaining aspect increased the students' interests toward the course. This increase was more evident for the students *who had less interest* in the lesson before. For instance, as the classes of the students were divided into groups based on gender in the second cycle, the teacher stated that the activities *removed the lack of interest* in the girl's groups. Additionally, the teacher reported the same *interest increase for this gender* in the mixed classroom during the first cycle as follows:

> *C1_A1_T: At the beginning of the year, for example, this is what is common in female students. At the point of computer use, I observed that they were a bit lagged behind the boys. However, when I look at it now, I think that especially the girls were very eager for this. I think their interest and motivation increased in using computer, using robots, assembling those robot parts, coding section. In fact, there is not much fear or indifference in our male students, which is classic, like using the computer, such as using it immediately, but I observed here that the interest of our female students and students who were not interested in it has increased with these activities.*

> *C1_A1_T: Sene başlarında mesela kız öğrencilerin genel de olan da zaten budur hani gözlemlediğim. Bilgisayar kullanımı noktasında hani erkeklere göre biraz daha geri planda olduğunu gözlemliyordum. Şu anda ama baktığım zaman özellikle kız öğrencilerimin bu konuda çok istekli olduklarını onların bilgisayar kullanma, robotları kullanma noktasında, o robot parçalarını takma birleştirme, kodlama bölümünde hani ilgilerinin ve motivasyonlarının arttığını düşünüyorum. Zaten hani erkek öğrencilerimizde hani klasiktir hani bilgisayarı hani böyle hemen kullanma şey noktalarında hani korkma ya da ilgisizlik pek yoktur ama kız öğrencilerimiz ve daha çok ilgi duymayan öğrencilerimizin de ilgilerinin arttığını gözlemledim.*

The teacher also touched upon the motivational contribution of activities for science course during the interviews (f=9). According to him, the students were *willing to perform similar activities* in science courses, too. This referred to an *increase in their interest* in that course. This increase was expressed by the teacher in one of the early activities of the implementation as follows:

C1_A1_T: I think the interest and motivation in science course increased.

C1_A1_T: Fen bilgisi dersindeki ilgi ve motivasyonun arttığını düşünüyorum.

According to the findings, the activities also contributed to students motivationally by providing them *success feeling*. The teacher described this sense during the interviews of the activities in the second cycle (including Activity-1, *f*=1 and Activity-4, *f*=2, based on the data in Table 4.49). According to him, the activities gave the students success feeling which was impossible to reach in other courses. In addition to this general expression, he also commented on the same feeling as a motivational contribution to one of the special education students in one of the groups as follows:

C2_A1_T: We have a special education student, a student with learning difficulties. It was positive and nice that that the students, who was in male classroom, wanted to come to classroom in between lunch time and spend time outside the classroom with these activities. It is nice to have an interest in them, to feel that I can do it, to experience that feeling. It had a contribution to us like that.

C2_A1_T: Özel eğitim öğrencisi, öğrenim güçlüğü çeken bir öğrencimiz var. Erkek sınıfında olan bu kaynaştırma öğrencisi dediğimiz öğrencilerimiz mesela öğle arasında gelip ders dışı zamanda da bu etkinliklerle vakit geçirmek istemesi olumlu ve güzel bir şey. İlgi duyması, ben yapabileceğim hissini alması, onun o duyguyu yaşaması güzel bir şey. Böyle bize bir katkısı oldu.

The students also referred to *the feeling of being successful.* According to the findings in Table 4.49, only two students reported the feeling of being successful during the focus group meeting of the first activity (*f*=2) in the first cycle. In contrast, in the second cycle, one student in each activity except for the last activity mentioned this contribution in the second cycle. According to the students, completing the activity properly and putting a product in the end made them happy. A dialogue implying this feeling took place in the second cycle's focus group meeting of the first event as follows:

C2_A1_FG3_S2: Sir, we like to do this and run it.

C2_A1_FG3_S1: Yes, we felt talented.

C2_A1_FG3_S2: Hocam, bunu yapıp çalıştırmak hoşumuza gitti.

C2_A1_FG3_S1: Evet kendimizi yetenekli hissettik.

Contributions to Teacher

According to the findings, the activities contributed to the teacher as well as the students. These contributions were clustered under the category of professional development. This theme and the related category were illustrated in Figure 4-23.

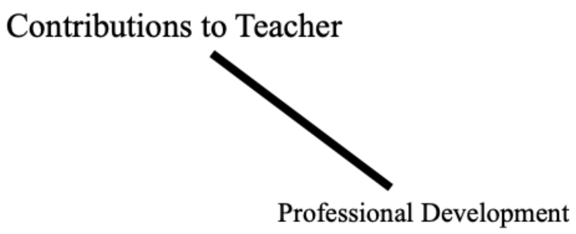

Figure 4-23 Categories of Contributions to Teacher

The data sources for the theme were the interviews with the teacher and the students in both cycles of the implementation. However, only the teacher commented on the contributions of the activities for himself. Therefore, a code tree which included the category of professional development of the teacher and the related codes listed from the most cited to the least by the teacher during the interviews presented in Table 4.50. The professional development category and the related codes were elaborated on after this table.

Table 4.50 The Code Tree of Contributions to Teacher Theme

Categories/Codes	Σf
Professional Development	**90**
Interest for research	42
Instructional change	39
Communication	9

Professional Development

The contributions of the activities to the teacher were asked to the teacher during the interviews. According to the responses of him, *the professional development* of the teacher as a contribution of the activities appeared in different ways. In one of them, the teacher expressed an *increase in new interest under various research subjects*. In addition, these activities brought him new experiences in the field of his profession. These experiences accompanied *changes in his used instructional approaches*. For instance, these activities led him to implement different instructional plans, or they showed to him the importance of using different teaching methods more obvious. The teacher also reported that *communication with the students* improved with these activities. The frequency distribution of his descriptions concerning these aspects of his professional development was presented in Table 4.51.

Table 4.51 Frequency Distribution of Codes belongs to Category of Professional Development

	Codes/**Participants**	**Activity 1** **T**	**Activity 2** **T**	**Activity 3** **T**	**Activity 4** **T**
Cycle 1	Interest for research	7	-	-	-
	Instructional change	3	1	2	-
	Communication	-	-	-	-
Cycle 2	Interest for research	-	-	-	1
	Instructional change	1	-	-	2
	Communication	3	-	1	2

Interest for Research

According to the findings provided in Table 4.51, the teacher expressed the majority of his descriptions about the contribution of the activities to himself concerning the *interest in research* during the interview of Activity-1 (*f*=7) in the first cycle. Additionally, he referred to this contribution at the end of the implementation last time (*f*=1) in the second cycle. According to the teacher, these activities prompted him to investigate the possibility of *conducting the activities with other courses* such as math or art besides science. In addition, he found himself in a new research trend with these activities regarding the use of robots. This trend started as *searching the robot firm's developments* closely and continued with *the use of different robot kits.* He expressed his research interest in using the robot parts in another system in these kits as follows:

> *C2_A1_T: For example, I thought that the sensors used in Ardunio can be attached to these robots. I also had a friend who did it. The sensors are more in Ardunio. I had the desire to investigate whether I would use different materials for the solution suggestions that the children gave.*
>
> *C2_A1_T: Bunu mesela ardunio'daki kullanılan algılayıcıların bu robotlara takılabileceğini, olabileceğini düşündüm. Yapan bir arkadaşım da vardı. Ardunio'da biraz daha algılayıcılar daha fazla algılayıcı ya da o malzemeleri kullanıp, çocukların o vermiş olduğu çözüm önerilerine yönelik farklı algılayıcılar kullanıp kullanmayacağımı araştırma isteği uyandırdı bende.*

Instructional Change

The contributions of the activities in terms of *the change in the instructional method* and *the planning of the instruction* were also reported by the teacher during the data collection process. In detail, the teacher defined *the instructional change* as one of the contributions of the activities almost throughout the implementation process in the first cycle except for the last activity. The majority of his descriptions belonged to the interview meeting of the first activity (*f*=3) in this cycle. In the second cycle, he referred to these changes as a contribution only during the interview of Activity-1 (*f*=1) and Activity-4 (*f*=2), based on the finding provided in Table 4.51.

According to the teacher, the activities encouraged him to plan the instruction that *the students would be more active*. The reason behind this decision was that the situation that the students were bored in the normal course hours was not observed during these activities. Since the students worked more actively here, the teacher commented that this kind of planning could be done during the normal course hours. Apart from planning, these activities were also effective in terms of the methods used in teaching. One of these effects was *the use of class resources*. As a contribution of the activities, the teacher stated that he realized how effective the resources in these activities for involving the students in the learning process. In addition, these activities created awareness for the teacher at the point that *some students should be dealt with individually*. According to him, the activities were effective both for specifying these students and creating this perception. Another perception change on the instructional method with these activities was concerning *the importance of note taking* for him. The teacher touched upon the change at this point as follows:

> *C1_A2_T: I developed the idea that it is important for children to take notes and assign homework for some information to be permanent. After that, I will guide my students at this point when I am teaching in the course.*

> *C1_A2_T: Bazı bilgilerin havada kalmaması için çocukların not tutması, ödevlendirilmesinin bu noktada önemli olduğu fikri bende uyanmış oldu. Bundan sonra derslerimi anlatırken bu noktada öğrencilerimi yönlendireceğim.*

Communication

Development of the teacher's *communication with students* was another contribution of the activities reported by the teacher only during the implementation of the second cycle. In detail, he first expressed the communication contribution of the activities during the interview of Activity-1 (*f*=3) in this cycle. Then, he repeated it during the interview of Activity-3 (*f*=1) and Activity-4 (*f*=2). According to him, the activities were beneficial for the development of communication with students in general. However, the main reason for the communicational contribution was brought up only in this cycle was that the teacher was appointed to *a new school* in this part of the implementation. He expressed that these activities contributed to the development of communication with the students in this new environment. The activities were carried out by enabling the teacher to establish *a closer relationship with the students*. This made it easier for the teacher to *get used to the new environment*. He described it as in the following:

> *C2_A1_T: Also, I think that the activities developed my adaptation process in the school, getting used to my students, and their getting used to me by getting to know the students better, spending more time with them, having a dialogue with them.*
>
> *C2_A1_T: Ayrıca öğrencileri daha iyi tanıma, onlarla daha fazla vakit geçirme, onlarla diyalog halinde olmam hem okula uyum alışma sürecimi, öğrencilerin bana alışmasını, benim onlara alışmamı geliştirdiğini düşünüyorum.*

4.6 The guideline of problem-solving activities designed for middle school students to solve ill-structured problems in science by integrating Educational Robotics (RQ3)

The third sub-question of the study was to uncover *the guidelines of the activities* in which middle school students solved ill-structured science problems by using educational robots. The researcher utilized the relationships of codes that emerged in the previous two-sub questions to unveil this guideline in this part. Additionally, the previous findings related to the preparation of the activities and their modifications were also used to support these relationships. However, it should be noted from the beginning that the pattern of relationships that make up the guideline is tightly bound to the context of the activities that was formed for this study. For this reason, this guideline was created to assist the same activities that were put forward in a similar context more than the generalization of them for other activities and contexts.

Motivation of Students

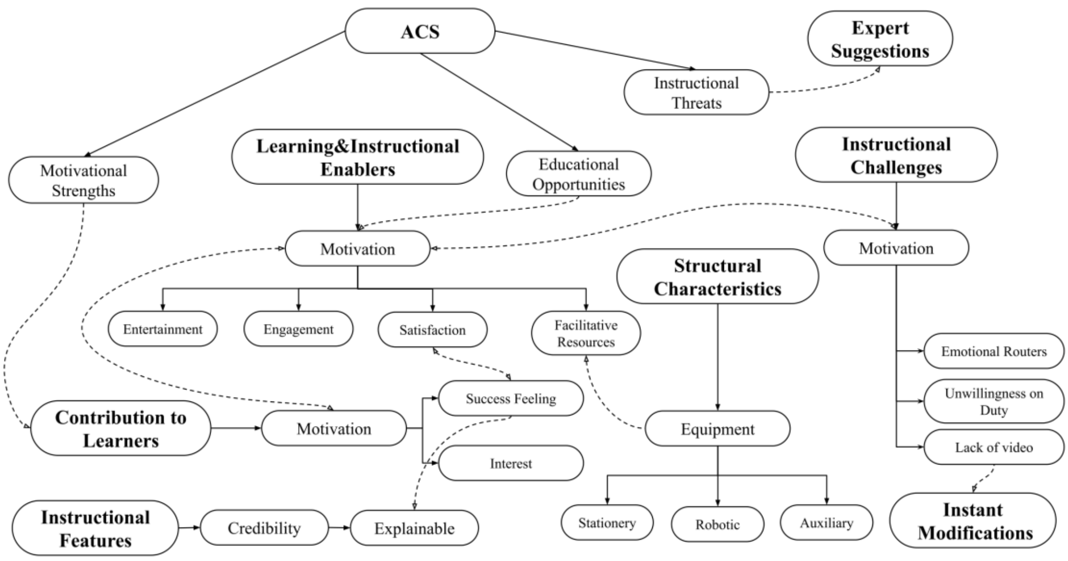

Figure 4-24 The Relationships of the Findings on Motivation of Students

The relations of the findings concerning *the motivation of the students* in activities were presented in Figure 4-24. According to this figure, the results of analysis of current status (ACS), which conducted in the school of the first implementation of the activities, indicated that one of the educational opportunities of the implementation was that the majority of the students were *willing* to conduct such activities and *their high interest in the technology* used in activities would motivate them toward the activities. However, some of them who had *low motivation levels* were considered as one of the threats and taken into consideration before the activities by the researcher. This threat was asked to the experts during the interviews of the preparation process of the activities. They suggested that *the interest of students* should be focused, especially in the first activity. Therefore, it could be the right decision for the order of the activity of *the robot factory* as the first activity since it kept one of the technology, *the robots,* in the foreground more than other activities.

The low motivation level considered before the implementation of the activities was also one of the challenges of the implementation process. The underlying reasons behind lack of motivation were identified as *unwillingness on duty, emotional routers,* and *lack of video,* based on the findings concerning the activities' challenges. In fact, the students worked in groups during the activities and they had exploited *division of labor* to manage the group works. Some students who did not want to perform the task assigned to him/her lowered the motivation of other group members. *Unwillingness in duties* was mostly observed at *programming* and *filling activity sheet* tasks. Therefore, these tasks should be made more attractive to the students by the teacher during the activities.

The other task in activities, which was exactly *the production task*, was not reported among the undesirable duties by the participants. Some of the utilized resources in the design might be the reason for this result. In fact, one of the resources of the activities, *the stationery materials*, was found to be one of the facilities of the activities. These materials used to simulate the problem scenario and/or as a part of the solution by the groups during the problem-solving process. They also engaged the students into the problem-solving process with *their attractive aspect* as well as other resources such as *visual materials*, *computers* and *the robots*. Therefore, all these facilitative resources should be made ready during the activities in order to motivate the students.

The emotional routers, which were related to the content of the ill-structured problem scenario and the content of the video watched at the beginning of the activity, were some of the factors that decreased the motivational level of the students during the activities. In detail, *the upsetting content* such as difficulties about disabled people or what happened in natural disasters decreased some students' motivational level during the problem-solving process. Apart from its content, *the absence of a video* at the beginning of the activities was another factor affecting the motivation of the students negatively. For this reason, with an instant modification on the activities after the first one, the activities began to be started with a video for the students. *The positive attitudes* of the students towards the video emerged as a result of the observations made during the lessons before. According to the results of this observation, the students reacted to the video with *great interest* during the course hours. Similarly, when *an introduction video* was utilized during the activities, it was found as one of the motivational sources of the activities. This video was produced by the researcher in conjunction with the corresponding activity's problem scenario. The specially prepared video as well as other visual materials of the activities were found to be one of the enablers of the activities as in one of the suggestions of experts. Therefore, a video preparing the students for the ill-structured problem scenario could be used at the beginning of the activities.

It was also observed that the students were working devotedly in the problem-solving process during the activities. Some of them did not go out even though they had a break and most of them were eager to do similar activities. *This engagement* contributed to the students as an increase in their interest toward the activities and the courses (IT and Science). Additionally, the activities motivated the students by giving them *success feeling*. In general, the students had the opportunity to reach at this feeling since they solved a problem as the result of the activity. Additionally, they created a product at the end of each activity. This, tangible side of the activities provided satisfaction for the students. These results (as a strength of the activities in current status analysis) emphasize the significance of the success feeling for the students' satisfaction level from the activities.

The presentation of the solutions to others at the end of activities, which could be effective for revealing the feeling of success, was a procedural modification for the second cycle. According to this change, while the students only made the presentation of their solution to their teachers in the first cycle, they started to present it to the whole class in the second cycle. This change contributed to the explainable side of the activities (one of the instructional features) and indicated that both *the* *design-related* and *the technical explanations* for others (teacher, classmates, other friends and relatives) should be promoted to evoke the students' success feelings. Therefore, regardless of its' effectiveness, the solutions for the ill-structured problems should be presented to some/all of these people in a suitable environment.

The entertaining aspect of the activities also motivated the students during the activities. Besides, *the activity process* as a whole, *the phases of them* (filling the activity sheet, programming the robot, and design the products) were seen as the source of the entrainment during the implementation process. Therefore, these phases should be taken their place during each activity process. Additionally, *the collaboration* in these phases had an entertaining aspect. The students who worked in groups reported that they engaged in the activities easily by sharing with groupmates. This indicates the importance of the collaboration in the problem-solving process of the activities. Therefore, the collaboration of students should be encouraged during the activities since the students worked better as a result of entertaining aspect of group works.

In conclusion, the following prescriptions are strongly advised to increase the students' motivation level during the activities:

- The students' low level of motivation should be taken into consideration before the implementation. The students' interests can be used to grab the attention of the students at the beginning of the activities. The technology, the stationery materials, and the visual materials used in activities were some of those interests. The activities should be equipped with these or similar attractive materials.
- The activity equipment offered to students should be chosen carefully since it motivates them during the problem-solving process. Visual materials (introduction video or slideshows) and other equipments (computers, robots, and stationery materials) should be made ready with great care before the activities.

- While creating the ill-structured problem scenarios or the visual materials presented at the beginning of the activities, the content that may have emotional effects on students should be avoided since they decrease the students' motivation during the activity process.
- The activities as a whole and the phases (filling activity sheet, programming, and production) were found as entertaining by the students. Therefore, these phases of the activity process should be kept during the implementation of the activities.
- Collaboration in group works is an important motivation source and it should be encouraged throughout the implementation process. However, working dynamics in the collaborative environment can change this effect. Therefore, it should be provided that all the group members are working in groups with an equal/close workload, and the tasks (filling the activity sheet, programming), which are not as attractive as the design task, should be encouraged for the students during the activity process.
- The success feeling is important for the students' motivation toward the activities. The students' solutions for the ill-structured problems and the product developed as a result of each activity are the sources of this feeling. Therefore, the solutions with the products for the ill-structured problems should be presented to others by the group members at the end of the activities.

Readiness for Activity

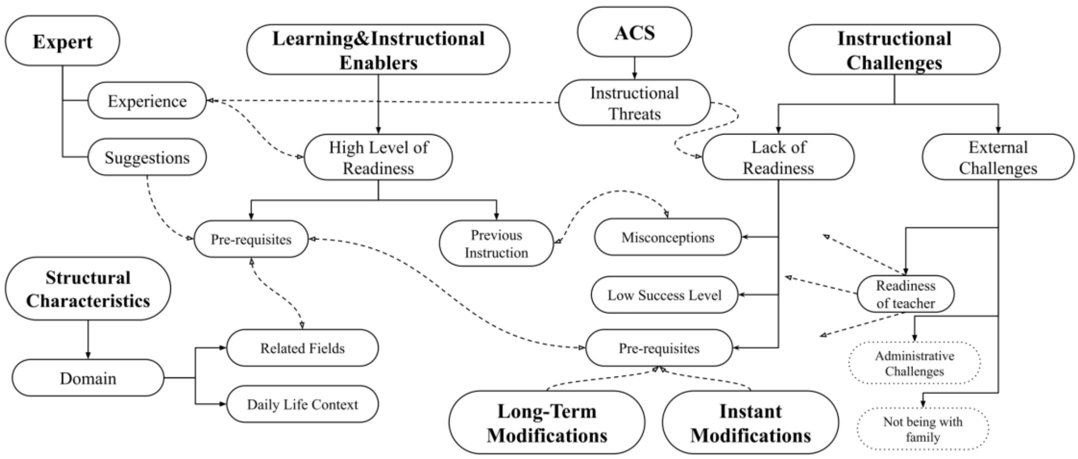

Figure 4-25 The Relationships of the Findings on Readiness of Students

For the guideline of the activities concerning *the readiness for the activities*, the relations of the findings were examined, and these relationships were illustrated in Figure 4-25. According to this figure, the analysis of current status (ACS) revealed that participants emphasized the instructional threats about *the students' readiness*. In detail, the findings of the analysis showed that *the lack of readiness* would be challenging during the implementation of activities. As one aspect of the readiness, the students' grade level was asked to experts who had previously conducted some activities with the same robot kits and to the students in both public and private middle schools. According to their experience, they conducted such activities at *the fifth-graders*, and they did not experience any difficulty concerning their grade level. Additionally, the other experts' suggestions also guided the choice of *the grade level* for the activities in the current study. There was an important warning given by these experts saying that *higher middle school levels* should not have been selected due to the national high school exam since both the school administrations and the parents did not look at these activities positively at these levels. Additional suggestion related to the students' readiness was that *learning of the related subjects in the science course* should have been waited to start the activities for the schedule of the activities. Moreover, a test could have been prepared and conducted to see the students' readiness level on prerequisites before the activities.

Another aspect of students' readiness, *the prerequisites of the activities*, was closely related to the associated fields of the activities. The finding for these fields, *the activities' domain characteristics*, indicated that the activities were highly interdisciplinary with the core fields as IT and science and others such as linguistic and art. In detail, the activities had a core interdisciplinary knowledge baseline in *the IT* and *science fields*. For this knowledge baseline, the necessity of the higher level of readiness on the pre-requisites could not be ignored. Therefore, the subjects described as pre-requisites in these areas should have been carefully completed before the activities.

According to findings, some of the prerequisite subjects reported by the participants overlapped with the *activity topics in the Science Course*. Along with the compatible science subjects with the activity as *temperature, sun and rays, force, natural disasters, environment and pollution,* other subject matters such as *electricity, sound, distance* formed the knowledge baseline of the activities for the science field. Additionally, *the knowledge of robotic pieces* and *the knowledge on programming* such as shapes of flowchart elements were the pre-requisites of the IT field. While the existence of the requirements in these areas made the process easy for the students, the absence of these prerequisites was a barrier to the activities.

In addition to the knowledge base in these fields, the required skills of *working collaboratively, programming, problem-solving,* and *use of stationery materials* were among the prerequisites that made the activity process difficult with their deficiency. The lack of these skills was found to be an obstacle to the success of the students on solving-problems during the activities. Therefore, the need of the pre-knowledge and skills indicated that *the low success level* on both those knowledge base courses and other courses (linguistic, art), and *the necessary skills* constituted one of the predictors of the lack of readiness for the activities.

The lack of readiness for the activities also appeared as *the misconceptions about previous learnings.* Some of these misconceptions belonged to the knowledge base in the fields mentioned above while some were related to the methods used. For example, some students had misconceptions about *the subject of Science Course* (force and friction) or *ITS Course (parts of robots)* while some of the others incorrectly filled *the fishbone on the activity sheet* during the activities. As a lack of readiness, these misconceptions were tried to be eliminated with some modifications made in the implementation process. As an instant modification, *a visual material* that the students could access quickly was prepared during the first cycle. This teaching aid consisted of an *interactive slide show* prepared for students to remind them of the robot parts. It was observed that many students used this teaching aid after its release, and several of them gave positive feedback about it.

The problem was instantly solved after this activity, but there were also several *long-term instructional modifications* on the activities aimed at the prerequisites of the activities. *A reminder paper* prepared for the robotic pieces, *a video* containing examples showing the different uses of robot parts, and another one explaining the construction of the robot were the visual materials utilized for the long-term modifications of the activities. Additionally, the teacher provided *a worked example* to remind the subject of filling the fishbone on the activity sheet and *a brainstorming activity* to remind the natural disasters and disability groups to the students before the activities. All these instructional modifications attempts could be used to remove the deficiency of the prerequisites of the activities.

In addition to the students' *readiness, the teacher's readiness* also affected the activity process during the implementation. The findings concerning the external challenges on the teacher's readiness indicated that the problems developed suddenly such as *health problems*, or case of *not being sufficient in design* affected the activity process negatively. Moreover, preparing himself/herself for the activities was crucial, according to the experts interviewed before the implementation of the activities. These experts foresaw that the teacher needed to work hard to become ready for activities.

To sum up, the following prescriptions presented below are highly recommended during the implementation of the activities for the readiness:

- The grade level of students is crucial for the implementation of the activities properly. They should neither be too young with low cognitive levels nor in the upper classes which have barriers such as exams for high schools.
- The schedule selected for the activities should be arranged, considering the subjects of the Science Course used in the activities. The pre-requisites for these subjects can be examined with a proper assessment method to determine the readiness of the students.
- The prerequisites of the activities indicate the knowledge baseline from the related fields of the activities. Some of the subjects in Science Course are consistent with the topics (force, temperature, sun rays, natural disasters, environment) employed for creating the activities. Furthermore, the subjects of the ITS Course are identified as the knowledge of robot pieces, flowchart, algorithm, and the editor. Removal of the deficiencies in these interrelated subjects before the activities is very important for the activities.
- The subject of electricity, sound, distance are the prerequisite subjects that are nonoverlapping prerequisites with the topics used for the creation of the activities in science. Elimination of the deficiencies of students' knowledge of these subjects will help them during the activity process, too.
- The needed skills (working collaboratively, problem-solving, programming, and design) are essential prerequisites of the activities, and the students should acquire them before the activities.
- The misconceptions in previous learnings should be eliminated to reach at sufficient prerequisites before the activities.
- The teaching aids on the most confusing topics (robotic pieces, construction of the robot) and the methods such as working examples and brainstorming

aiming at recalling the previous learnings (on filling the fishbone, the natural disasters, and disability groups) should be utilized during the activities so that the students can go on their activities more readily.

- The low success level of the student in related fields (science and IT) and others (linguistic, art) is one of the predictors of the lack of readiness for the activities. Special attention should be paid to the students who have low success level in those fields throughout the implementation process.
- All elements that affect the readiness of the teacher should be removed before the activities. Additionally, the extra workload for being ready to activities must be accepted by the teacher in order to carry out the activities properly.

Scaffolding in Activities

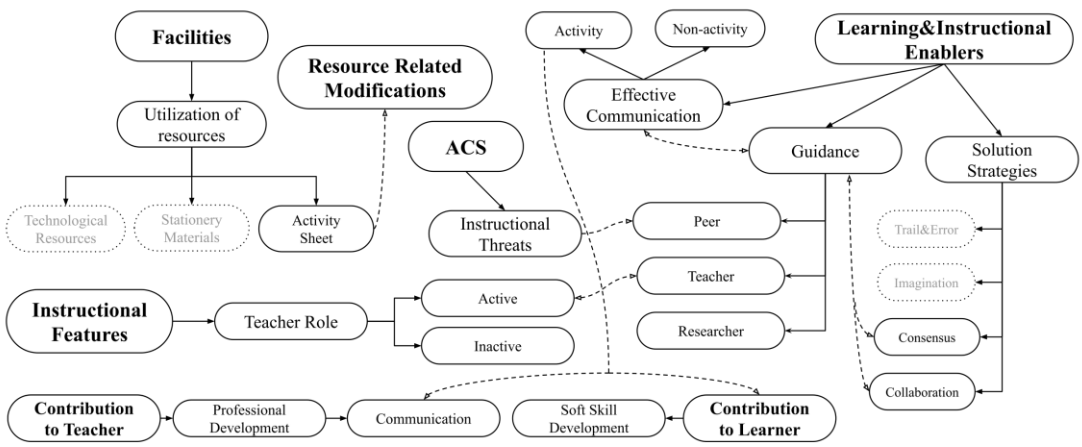

Figure 4-26 The Relationships of the Findings on Scaffolding in Activities

The relations of the findings regarding the scaffolding in activities were presented in Figure 4-26. According to these findings, one of the resources of the activities (also equipment of the activities), *the activity sheet*, was used as a pathway for the students to follow the problem-solving process. In fact, this sheet was containing the instructions about *the problem-solving steps* and it was prepared by the researcher and then checked by the experts before the implementation process. It had seven parts beginning with presenting the problem scenario and ending with the drawing of the algorithm that would be uploaded to the robots later. However, an additional part was put on it as a modification, which asked the students their choices on the solution proposals and its details. Both before and after this modification, *the activity sheet*, with its guidance on the ill-structured problem-solving process, was seen as one of the activities' essential facilities. Beside its facilitative aspect, the activity sheet was also found to be one of *the entertainment* sources during the activities. In fact, several students reported that filling the parts on the activity sheet was entertaining during the activity process. This entertainment was defined as one of *the activities' motivators*. However, the expression of some others indicated that *unwillingness in duty* that required the task of filling the activity sheet was *one of the reducers* of the motivation level. Therefore, it is clear that some of the students need to be motivated to use this scaffolding equipment (activity sheet) during the implementation process of activities.

Another enabler of the activities, *the guidance,* scaffolded the students when they tackled the challenges during almost all the phases of the activities. When the guidance process in the activities was examined, it was seen that there were three different sources of it in the activities. Two of these sources, *the teacher* and *the researcher*, pointed out the same direction of the guidance. In this direction, the instructors *helped students*, *controlled their work*, *gave feedback* about it, and *directed the activity process* when it was requested by the students. The role of teacher existed here as an active teaching method during the activities. With this active role, the teacher guided the students by asking them questions about their solutions and giving feedback to the students' questions in the process. However, the level of instructors' guidance decreased throughout the implementation process since the students experienced and got accustomed to the activities from beginning to the end.

As the third source, the students were also guided by the groupmates. *The peer-guidance* was found to be one of the sources of scaffolding during the activities. This guidance was mainly about *the robots* and *the design issues* in which the students had troubles during the activity process. The students got help from groupmates and looked up others ideas on these issues.

The students' effective communication with each other and with the teacher *during* and *out of the activities were found* interrelated with the guidance process. According to this two-way interaction, communication during the activity process contributed to the development of both the teacher's and the students' *communication styles*. However, a result of the analysis of the current status indicated one of the instructional threats of activities that some of the students would not share their ideas with others if they got afraid of *plagiarism*. This could negatively affect *the peer guidance* level in the learning environment. However, such a problem was not encountered during the activities, based on the findings. This was a very pleasing situation for the participated students.

Regardless of the source of guidance, when looking at the processes of finding solutions to the problems faced by students, two solution strategies were employed by the students as the *use of scaffolding*. Accordingly, the students utilized either *collaboration* or *consensus* with others as a solution strategy to overcome the problems encountered during the activities. These strategies were very important in the emergence of guidance for the students. Therefore, *the use of strategies* should be encouraged during the implementation of the activity process.

In conjunction with the findings' relations, the following prescriptions regarding the scaffolding in activities are advised:

- A material that provides a pathway for the students on the steps of the problem-solving process can ease the activity process.
- The guidance of the instructor for the students benefits from effective communication. Therefore, being in good communication with the students is necessary for the instructor who needs to actively guide them during the activities.

- The students should be encouraged to collaborate with the instructor and groupmates to overcome the activities' challenges in order to use of guidance of others effectively.
- Reaching consensus and collaboration are the key solution strategies for the peer guidance in activities. Therefore, employment of these strategies should be encouraged during the activities.

Collaboration in Activities

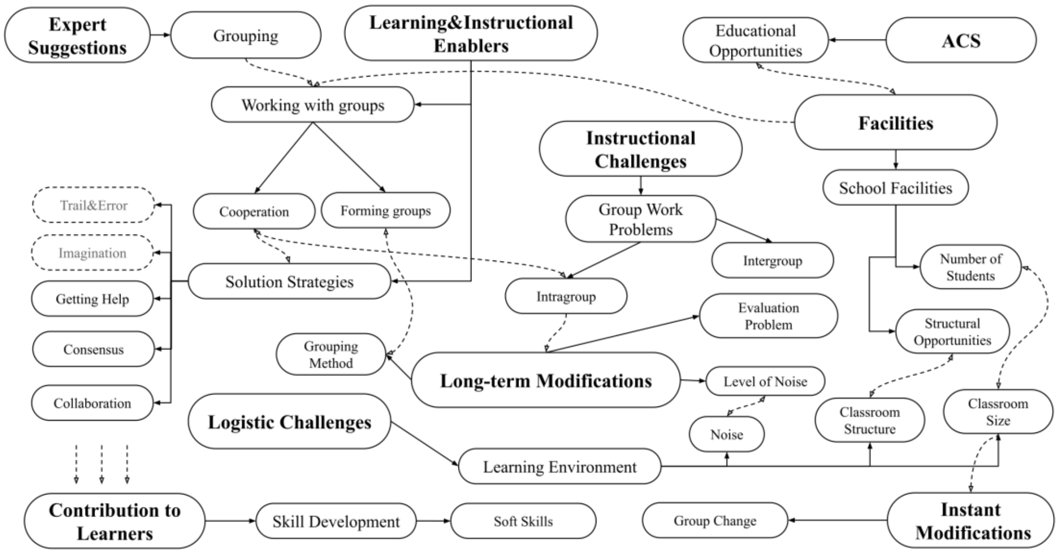

Figure 4-27 The Relationships of the Findings on Collaboration in Activities

The activities were conducted as group working, which allowed the students to collaborate with others, and resulted in several findings concerning this aspect of the activities. The relations between these findings were indicated in Figure 4-27. According to these findings, the expert suggestions before the activities directed the activities' organization as *the group works*. Additionally, several educational opportunities such as *the structure of the classroom* and *the number of the students* were the findings of analysis of current status contributing to the decision to conduct the activities collaboratively. These opportunities were also found to be the enablers of the activities under the school facilities category for mainly the first cycle of the implementation. However, *the classroom structure* is not appropriate for group work, and *crowded class sizes* in the second cycle were enough to turn this opportunity into a challenge for the learning environment.

Another educational challenge was *the noise problem* highly related to interactions of the group members and the groups during the collaboration in the activities. The *buzzer's voice, being over talker*, and *being novice in collaborative works* were identified as main reasons for this challenge. Continuous warnings were given to the students during activities to overcome this problem. Besides, as a long-term modification, *this warning* was put into activity prescriptions prepared for the second cycle of the implementation. Another modification was made for the small classroom size caused by the decrease in the students' attendance. According to this modification, *group changes* were made instantly in groups in which the students did not attend to the remaining part of the activity. However, a complete solution to this problem was not possible during the implementation process.

In contrast to these challenges, *working in groups collaboratively* was one of the enablers of the activities. *The cooperation* between the students positively affected the problem-solving process. However, several *intragroup problems* disrupted this effect by preventing students from adopting their groups. These problems emerged as the *conflicts in groups*, *resentments between the group members*, *mobbing in groups, negligence of division of labor*, and *the disengagement from the groups*. In order to minimize these problems, changes were made *in the grouping method*. A *systematic way* was followed in *forming the groups*, and *division of labor* within the groups was provided to make the collaboration in the activities better. As a result, *the creation of such issues as systematically* functioned as a facilitator of the activities' problem-solving process.

It was the result of another relationship with some *solution strategies* of the students that emerged as a result of the working in groups during the activity time. According to this finding, getting help from others as in the form of *collaboration* against the challenges and reaching *a consensus* for the decisions were the students' strategies to solve the problems during the activities. The adoption of group works during the activities was very important in the development of these strategies as well as other contributions to the students. Among these contributions, the students improved their *collaboration* and *communication skills* as soft skills by performing on group works during the implementation of the activities.

As a conclusion, the following prescriptions presented in the following are highly recommended for a collaborative learning environment during the implementation of the activities:

- The structure of the classroom should be appropriate for the group works as well as the number of students in the classroom. The number of students either too high or too low will not be feasible for the group works in activities.
- The noise created in group work during the activities is one of the most important challenges. In order to prevent this contextual problem, various warnings can be announced, and a rule should be put into the prescriptions of the activities.
- The intragroup problems (group conflicts, resentments, mobbing, negligence of division of labor, disengagement from the group) should be minimized during the activities. Forming the groups and performing the division of labor in groups systematically can be used against these problems for a better collaboration in activities.
- During the activities, several solution strategies (collaboration, consensus) of the students for encountered troubles could emerge through the group works. Therefore, in order to use these strategies sufficiently by students, the collaborative group works must be supported during the implementation of the activities.

Learning Outcomes & Settings in Activities

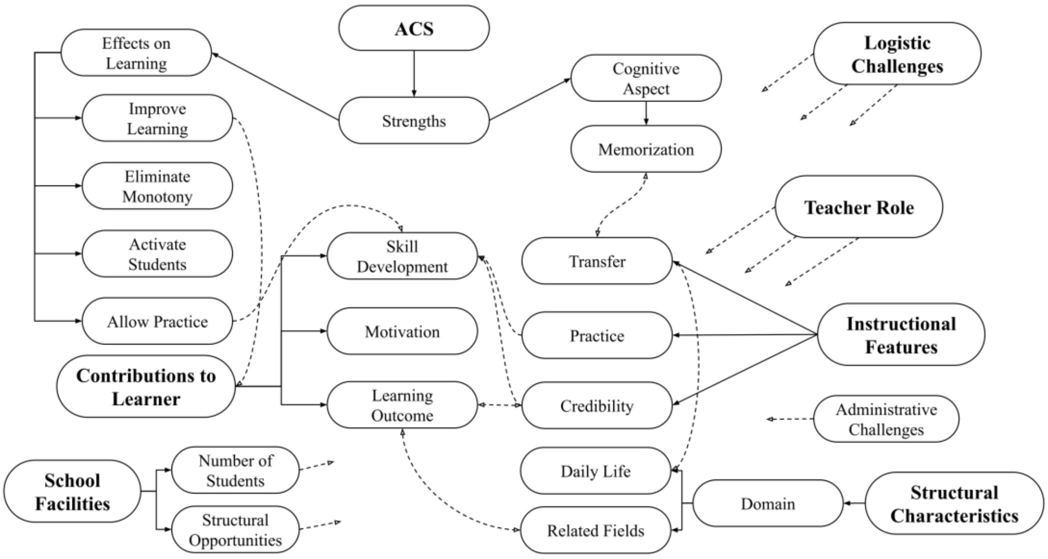

Figure 4-28 The Relationships of the Findings on Learning Outcomes and Settings in Activities

The relations of the findings indicating *the learning outcomes and settings* in activities were given in Figure 4-28. According to this figure, the analysis of the current status (ACS) results indicated that the activities could positively affect the students' learning by *improving learning*, *eliminating monotony*, *activating students*, and *allowing them to practice*. The learning improvement was found among the sub-research question (2) findings as *contributions to the learner*. According to these findings, the activities contributed to the students as *learning outcomes* on several courses. Among these courses, the students obtained the ITS Course objectives on specific topics such as the subject of the algorithm, programming, and problem-solving during the activities. Moreover, the students recalled the previous learnings. They got new information from the scenario or the video's content that introduced the ill-structured problem statement to the students (for Science Course). The learning outcomes in these courses and other courses (Linguistic, Art, Math) were found to be closely related to the fields of the activities as the domain structures of them.

The domain of the activities, which was found as multidisciplinary, was also related to the *daily life context*. The similarity of the ill-structured problems with everyday problems constituted the majority of this relationship. In addition, the utilized technology in activities such as robots, computers were among real-life technology. Therefore, the participants thought that the activities were highly interrelated with daily life. This close relation constituted one of the instructional features of the activities. According to this characteristic, *the transfer of activities to daily life* occurred easily. The students could utilize the activities in daily life individually and/or help other people. Like these transfer areas, the others i.e, *transfer to professional life, education,* or *other projects*, indicated that the learnings in activities carried outside the activities. This finding overlapped with one of the analysis of the current status results as the strength of the activities about the cognitive aspect. According to this aspect, the activities got away the students from just memorizing the topics and giving them the opportunity of practice.

As one of the instructional features, *the practice* in the activities allowed students to apply their learnings to both ITS and Science Courses and to have better understandings of the related subjects in those courses. Moreover, with active participation in the activities, the students experienced *active learning settings*. In those settings, the students utilized division of labor to perform on several tasks (filling activity sheet, robotic, and design). According to this division method, the students who took responsibility for one of these tasks also collaboratively participated in other tasks. Furthermore, some of the students utilized the discovery method to obtain the required information to do these tasks in *collaborative learning settings.*

As a result of practice in these learning settings, the activities were found as contributing learners in learning outcomes on the related fields (IT, science, others), motivation, and skill development. Those contributed skills (soft, CT, ICT, and design) and motivational contributions (interest, success feeling) indicated that the activities could have a multifaceted effect on students' learnings. However, the measurement of the impact of learning in such learning settings was not easy.

One of the instructional features of the activities, *credibility*, might help in the assessment of the learnings in activities. According to this feature, the activities had *general goals* (problem-solving, developing product, use of educational robots) and *activity-based goals* (upgrade robots, protect people, and protect the environment). These general goals can shed light on the assessment process of the activities. Additionally, the activities were found to be explainable. In this aspect, *the design-related explanations* and *technical explanations* of the groups (for classmates, the teacher, and the others) could be put into the activities' assessment process. *The evaluable tools* utilized in the activities (activity sheets, peer evaluation form) can also be utilized to the assessment of the learnings in activities.

The role of the teacher in the learning settings of the activities were mostly found as *being active*. In this active role, the teacher was *the source of information*. He used *the presentation method* to introduce and summarize the topics in some parts of the activities. Additionally, he supported the students by controlling their work and giving feedback to them and responding to their questions. In the remaining part of the activities, the teacher only observed the students while they were progressing through the problem-solving process.

The school facilities in the learning settings of the activities eased the students' problem-solving process. One of those facilities was *the number of students* in the activities. According to findings concerning the number of the students in activities, the activities should have been conducted with the classroom not crowded a lot but also with enough number of students to provide a collaborative learning environment. Additionally, the number of *equipment of the activities* (robotic, stationery, and auxiliary materials) should be determined according to the number of the students since the distribution of these materials could be problematic in the learning settings. In fact, one of the study's findings indicated that the distribution of these materials *randomly* resulted in several logistic challenges in contrast to delivery method based on *the lot* as one of the enablers of the activities. The other resource problems could be about *the durability of the robots*. *The breakdowns of the robot's pieces* emerged as a need for extra robot kits/pieces in the learning settings. *An auxiliary material (soldering machine)* can also be used to repair these pieces immediately. Therefore, it should be getting ready in the learning environment. The *laboratory's infrastructure* should be controlled and upgraded before the activities since it can trigger several problems, such as the connection of the robots to the computers.

Additionally, the administrative challenges for the activities affected the learning in the activities negatively. *The tasks* that were given to the teacher simultaneously during the activity time interrupted the activity process, and the researcher kept the activities going during the implementation process. This may be more problematic when the activities are conducted without a substitute. Moreover, *a compulsory student exchange* took place in one of the implementation classes. The students who attended the classroom had studied other programming subjects instead of the programming of robots. The adaptation of these students was made by assigning them to existing groups. However, several challenges about these students' engagements with new groups were experienced in the remaining weeks of the implementation. Therefore, it could be more appropriate to teach *the students in all class groups the same robot subjects* in order to avoid this type of problem.

In conjunction with the relations of the findings, the following prescriptions regarding the learning outcomes and settings in activities are advised:

- Since the activities were found to be highly multidisciplinary, several features of their credibility can be used for the assessment of the outcomes. The general goals and activity-based goals should be taken into consideration while preparing the assessment of the activities. Besides, the activities were found as explainable to others. Therefore, the assessment process can contain the design-related explanations and technical explanations of the groups. The activity sheets, reflection papers, and peer evaluation forms made ready before the activities may also be utilized in the assessment process.

- The role of the teacher was found to be highly active in the learning environment of the activities. Therefore, the activities may not be appropriate for self-learning environments. The activities are highly recommended to conduct with the instructor.

- The number of students in activities should be determined, considering appropriateness for the collaborative learning environment. The number of materials (robot kits, stationery materials) should also be provided according to the number of students.
- For the distribution of equipment of the activities (robot kits, stationery materials), a method based on the lot should be preferred rather than a random distribution.
- The durability of the robotic pieces is not very well. Therefore, extra robot kits should be ready before the activities. Additionally, a soldering machine can be utilized for the breakdowns of robots.
- The infrastructure of the laboratory should be controlled for the technical problems before the implementation of the activities.
- The activities can be conducted with a substitute for the teacher in order to continue with the hesitation of administrative tasks. If it not possible, these tasks should be done before or after the activities by the teacher.
- To be ready for the cases of the possible classroom changes, it should be more appropriate to proceed with the same speed and with the same subjects in the ITS Course for all classrooms.

CHAPTER 5

DISCUSSION AND CONCLUSION

The aim of the study was to explore the design issues of collaborative problem-solving activities involving ill-structured problems and using educational robots by combining Information Technologies and Software (ITS), and Science Courses for middle school students. In conjunction with this purpose, the main question, "How should problem-solving activities for middle school students be designed to solve ill-structured problems in science using Educational Robotics?" was addressed in the course of the research. Specifically, three sub-questions of the study were investigated in order to unveil the design fundamentals of ill-structured problem-solving activities. These focused on arriving at a determination of the enablers and challenges, the characteristics, and the guideline of such activities.

A formative research design was followed throughout the study. In the first part of the research, the literature review and experts opinions guided the preparation of the problem-solving activities that were developed in line with the content of ITS and Science Courses. The objectives were chosen at the fifth grade level for both courses. Subjects were associated with the problem-solving and programming unit for ITS Course and related to physical events, creatures, and life units in the Science Course. In the second part, the data were collected throughout two cycles of the implementation in two different public schools. During these cycles, several changes were made on the activities based on interviews with participants, researcher observations, and video recordings. These modifications were identified as instant and long-term modifications, since some of them applied immediately to the following activities and others applied between the cycles respectively. In addition, the research questions were investigated using data collected as opinions of the teacher and students with semi-structured interviews, and students' text-supported drawings, reflection papers, group activity sheets, and tests on subjects related to the activities.

Key findings of the research were discussed in this section through the parts based on research questions. These parts were, specifically: enablers, challenges, characteristics, and the guideline for problem-solving activities in which ill-structured problems in science were solved through the use of educational robots. The findings related to each part were reported with the insights of the researcher and the results of previous studies in the literature. Additionally, the research conclusion was elaborated in line with the implications and suggestions for stakeholders of the activities and for further studies at the end of the chapter.

5.1 Major Findings and Discussion

5.1.1 Primary Enablers of Problem Solving Activities

Learning and Instructional Enablers

Motivation

The motivation of students during the activities was identified as an important enabler of the activities in which the students solve ill-structured problems with educational robots. Several key factors for this enabler have been detected, including *entertainment, facilitative resources, satisfaction, and engagement.* The distribution of the data among the activities indicated that the majority of students reported entertainment in activities at the beginning of the implementation processes in both cycles. The novelty effect of the activities on the students could be the underlying factor of this distribution since as indicated in the literature, the students usually enjoyed activities more when they were dealing with something innovative and challenging, which was seen as the best motivator in such learning environments (Theodoropoulos et al., 2017). In addition, the first activity specifically required students to imagine the scenario in which they needed to act as a robot engineer in a hypothetical robot factory. This imagination could also add more fun to this activity because there was no such requirement for other activities formed with more realistic and serious problem scenarios.

Regardless of whether or not the problem scenario was fun, according to most of the participants, *the overall activity* was entertaining. This finding is consistent with the findings of other studies investigating similar robotic activities. The students were working in an entertaining learning environment in those activities (Atmatzidou & Demetriadis, 2017; Gürkanlı, 2018), which was fun and exciting (Scaradozzi et al., 2019); therefore, such activities might be motivating for students in comparison to paper-based activities (Gyebi, Hanheide, & Cielniak, 2017). Some student participants, however, may find robotic tasks out of their areas of interests (Xenos et al., 2017). Therefore, the entertaining aspect of the overall activity cannot be considered the only motivating factor for the entire problem-solving process.

The participants in this study expressed that some phases of the activities (specifically paper work, programming, and production) were entertaining during the problem-solving process. Similarly, in other studies *programming* with robots (Pásztor, Pap-szigeti, & Török, 2013) or without them (Attaway, 2013) was sufficient to make the subjects enjoyable. In addition, manipulation of the physical objects in activities encouraged student learning through the entertaining learning environment (Davison, Wijnen, van der Meij, Reidsma, & Evers, 2019). Although the objects in that research referred to preparation (e.g., placing pots on balance) and initialization of an experiment (e.g., removing wooden blocks from under the balance), it can nonetheless help us to understand the level of entertainment in *the production phase* of the current problem-solving activities, in which the students used stationery materials to prepare their robots for the solution of ill-structured problems. In addition, *the filling of activity sheets*, which primarily aimed to guide students through the ill-structured problem-solving process, appeared to be an effective way to motivate students by providing them entertainment during the problem-solving activities.

The facilitative resources often encouraged students to work on the problem-solving process in the activities. For instance, some of the activities began with a video introducing the problem statement at the beginning of the activities. The main purpose of this video was to get the students' attention to the ill-structured problem. In fact, it was one of the steps of Gagne's Nine Events of Instruction, one of the most commonly used methods in educational settings to grab students' attention on a subject. According to the findings of the current study, the use of the introduction video for the same purpose motivated students on the ill-structured problem-solving activities.

In addition, *the equipment of activities*, such as computers, robots, and stationery materials were other resources that motivated students during the activities. Among these resources, *the stationery materials* were viewed as quite attractive by students. In fact, the main goal of several students was to complete the previous phases of the activities quickly in order to use these stationery materials as soon as possible. Additionally, *technical equipment* such as computers and robots were also appealing for the students. Several studies in the literature indicated that the use of robots enhanced students' motivation during their learning (Agatolio, Pivetti, Di Battista, Menegatti, & Moro, 2017; Kubilinskiene, Zilinskiene, Dagiene, & Sinkevicius, 2017; Stergiopoulou, Karatrantou, & Panagiotakopoulos, 2017) as they provide entertainment (Mubin, Stevens, Shahid, Mahmud, & Dong, 2013a) due to their functionality (Chetty, 2017), and because of the editor used to program them (Blankenship, 2014). However, participants in the current study did not explicitly define the programming editor, Idea, as one of the motivators of ill-structured problem-solving activities.

There were also several indicators of student *satisfaction* in the problem-solving activities of the current study. The findings indicated that the students were motivated by these satisfying sources, which were specifically identified as working with groups, developing a solution or product, and getting a certificate at the end of the implementation process. In detail, most of the group members were very pleased to work together to solve an ill-structured problem during the activities. Therefore, one of the motivators of the learning environment might be the collaborative nature of the activities as indicated in another study by Theodoropoulos et al. (2017). Following this collaborative work, the majority of groups developed a solution with a product at the end of the problem-solving process. The resolution of the problem or/and the product development as the solution could therefore be the source of satisfaction during the activities. According to Balogh and Petrovič (2020), the most satisfying aspect of the activities was the efforts of the students and the quality of the solutions in the process. As a result of this effort, the problem solver met a need with the functional perspective of robots in such activities (Slangen et al., 2011). Therefore, the physical representation of the effort became tangible and satisfactory for the learner (Geist, 2016). Iterative design process used to achieve this tangible result provided the students a gradual way to satisfy their building curiosity (A. Sullivan, Strawhacker, & Bers, 2017) and they became motivated at the end of the activity since they could see the results of the effort immediately in the learning process (Theodoropoulos et al., 2017). However, the resources of the activities should be carefully identified since the inadequacy of these resources could not be sufficient to satisfy the students' imagination in their designs, as expressed by Üçgül (2012).

When the resources of the activities met the students' needs, they tended to be very active in intensive group works, which encompassed an engagement into the problem-solving process during the activities. The students' *engagement* into the problem-solving process was identified as one of the motivational enablers of the activities. One of the indicators of this commitment was that the majority of the students did not prefer to go out at the break time during the activities and instead wished to participate in further activities. Like these activities, the overall activity process was reported as engaging for the student participants by Stergiopoulou et al., (2017) and Gyebi et al., (2017), and the teachers (Theodoropoulos et al., 2017) in learning environments. In addition, even though the learning environment was based on a cooperative, rather than competitive setting in the current study, several groups wanted to do better than others during the activities. Some of the further explanations concerning this wish indicated that there was a secret competition between the groups. This result coincided with the findings of other studies that conducted robotic activities in competitive learning environments. According to these studies' results, the spirit of competition in tournament or races provided an engagement for the students in robotic activities (Üçgül, 2012) and encouraged them to overcome the challenges in the learning environment (Atmatzidou & Demetriadis, 2017).

Guidance

Guidance is one of the requirements of problem-based robotic activities in order for the participants to complete all steps in the problem-solving process (Leoste & Heidmets, 2020) with detailed instructions on how to perform these steps for effective learning (Atmatzidou & Demetriadis, 2017) or little help in modeling or coaching to help them how to be self-directed (Ma & Williams, 2013). This requirement has been identified as one of the enablers of the activities in the current study. The findings indicated the sources of the guidance as *the teacher, the researcher, and peers* during the problem-solving activities. Similarly, the sources of assistance were listed as the teachers, classmates, and robots in another study. Accordingly, indirect guidance was provided by the longitudinal support of the teacher, while classmates provided direct guidance, including immediate solutions to barriers in the process in this study. In addition, the functions of the robots allowed students to hear instructions repeatedly during the implementation process (Chiang, Zheng, Cheng, & Chen, 2020). Apart from this guidance taken from robots, other types of assistance were consistent with the findings of the current study.

According to the findings of the current study, *the teacher's guidance* was mostly in the form of controlling work, helping students and directing the problem-solving process. It was clear that most of this assistance was provided via indirect scaffolding. However, it was also reported that the teacher was sometimes directly involved in the problem-solving process to remind the students of certain topics such as the explanation of the robotic parts or programming issues. These findings were consistent with the findings in the literature. According to Üçgül (2012), the programming and combination of robotic pieces were the most struggling phases of the robotic activities. Therefore, the guidance of the instructor was very important for these tasks. The programming problems could be removed by debugging as a type of teacher guidance in these phases (Gürkanlı, 2018). The students who were guided with this strategy would learn to manage locating and solving errors by themselves later and this gave them great pleasure (Atmatzidou & Demetriadis, 2017). Therefore, they got good programming practice with clear guidance including relevant feedback that would make sense for them in the process of the activity (Kazimoglu, Kiernan, Bacon, & MacKinnon, 2012).

Students who identified the activity process as struggling might gradually succeed in the activities with some inspired guidance from the teacher (Catlin, 2017) as some of the instructor's guidance was intended to direct the process of the activities. One of the examples for this directive guidance was the assistance of the instructor with regard to problem-solving steps. In a number of studies, the need of instructor assistance in the problem-solving process was reported many times on the correct choice of steps to solve the problem (Chen, 2010; Angeli et al., 2016), or finding a specific way to solve an ill-structured problem (Bellas, Salgado, Blanco, & Duro, 2019). The reason behind the need for guidance in the ill-structured problem-solving process was expressed by Ma and Williams (2013) as "children who have limited experience in robotics and nonroutine problem solving would quickly lose interest and focus if support is not readily available" (p.26). Therefore, they needed to develop problem-solving skills gradually with an external support (Angeli et al., 2016). This may explain the difference in frequency distribution of the data in the current study, since the teacher's guidance was expressed mostly during the first activity interviews and decreased throughout the implementation process of the problem-solving activities in both cycles.

Another remarkable finding of the current study indicated that guidance from neither the researcher nor peer was reported as frequently as the guidance provided by the teacher during the implementation process in both cycles. In addition, the frequency of student descriptions relating to the guidance of the researcher gradually increased throughout the activities in the second cycle, as opposed to the guidance of the teacher. The reason might be that the student participants did not know the researcher well at the beginning of the implementation process and avoided asking him questions, even though the researcher and the teacher were equally responsible for the guidance during the activities. Similarly, peer guidance was not reported by the participants during some of the interviews. However, it was observed that the students asked for help from their group mates several times during the problem-solving process. In the interviews, they expressed this help as *the exchange of ideas* about robots and design issues, which was quite compatible with the findings of another research study. According to Hong, Yu and Chen (2011), opportunities for new actions might be explored under peer guidance. However, peer guidance did not always provide clear advice. It existed mostly as a means of sharing of information with others. In the current study, this sharing had a positive impact on the activity process, since students solved lots of group problems themselves through this guidance during the implementation of problem-solving activities.

High Level of Readiness

A high level of readiness, characterized by the adequacy of *pre-requisites* and *previous instruction*, enabled the activities. The importance of pre-requisites for the activities was reported by the participants as impacting knowledge on subjects in the Science Course (temperature, sun rays, force, natural disasters, environment, pollution, electricity, sound, and distance) and ITS course (the knowledge of robot pieces, the knowledge of flowchart, and algorithm). According to the findings of another study, comprehensive prior knowledge on the subjects of the activity, specifically well-developed domain knowledge and understandings, was needed for a high level of readiness (Gibbon, 2007), which was a primary requirement for solving ill-structured problems (Shin et al., 2003). Prior knowledge should therefore already have been taught to the students before the activities (Ching et al., 2019) or tools should be put in place to provide information on pre-requisite subjects during the activities, otherwise students are not able to develop a better solution for the problem (Kazimoglu et al., 2012). In the current study, an example of these tools was added to the activity process as an instant modification after students had asked too many questions about robot pieces. An interactive slide show was prepared to introduce to the students sensors and activators of the robot and their functions. This slide was then kept open on the smart board throughout the activity process. After its release, it was observed that students who did not know these pieces or who forgot them for a moment tended to use this tool while they were solving the problem.

In addition to prior knowledge, several pre-requisite skills emerged as factors affecting student readiness for the activities. In detail, problem-solving, working collaboratively, and using or programming robots were required skills during the ill-structured problem activity process. It was noted by the participants that the students who were good at these skills completed the activity process successfully during the implementation process. Notably, related research identified some of these skills as essential skills for such activities. According to Dwivedi and Dwivedi (2017), students needed to gain some insight into the use of variables and mathematical operations to experience all the functionality of the robots in activities. Without the requisite expertise in the disposal, designing, and construction of a robot, performing the task could be very challenging and time-consuming for students (Chalmers & Nason, 2017), or result in a failure to follow the scientific inquiry process during the activities (Williams et al., 2007).

The remaining learning and instructional enablers of the activities spoke to the superiority of working collaboratively with group members as opposed to working alone during the problem-solving process. The method for forming these groups eased the implementation process of the activities, as well as the division of labor in the groups. Additionally, the students’ solution strategies for the challenges faced during the activities were the important enablers of the activities. Among them, trial-error was mostly used for technical challenges in the programming and production phases of the activities. The students foresaw the result of their solution using the imagination strategy, described in the results section. In addition, they also sought to make sense of the problem statement using the same strategy. Collaboration was applied to get help from others and consensus was used to find the most appropriate solution offer of the group members. In some of these solution strategies, they used another activity enabler, effective communication. Effective communication, emerging through friendships throughout the classroom, was observed as out-of-activity communication. Lastly, the essence of the activities such as time (sufficiency of time and the schedule) and the problem scenario (comprehensibility and relation with the context) enabled the problem-solving process during the implementation of the activities.

Facilities

According to the findings of the current study, *facilities* – defined as *utilization of resources* and *school facilities* – were the key enablers of the problem-solving activities. As stated by Khanlari (2016), the school administrations should particularly provide the following resources in order to improve the instructional use of robotics in the classrooms:

- Technical support,
- Instructional documents,
- Tools and software packages,
- Training.

The resources had a positive effect on the progress of problem-solving activities when used appropriately. In detail, the technological resources in activities such as the proper infrastructure of laboratory and well-equipped robots seemed to facilitate the activities. Computers were the most striking components of the laboratory, since a number of issues, such as problems with robot connections or reducing the time spent by students during programming, depended on these tools. Therefore, the well-being of the laboratory infrastructure, as indicated by Theodoropoulos et al. (2017) and Sergeyev (2017), was important for the proper functioning of the problem-solving activities as well as available laboratories in the school (Gyebi et al., 2017). The laboratory used in the current study was open to students beyond the duration of activities. However, only a couple of them came to the laboratory and were interested in computers rather than their problem-solving activities in these free times.

According to Sullivan et al. (2017), the physical space of the learning environment where students engage with new technology through collaboration and communication with others should be arranged using the available resources. As stated in this study, the first phase of the activities was carried out in *the library* of the school in the second cycle of the implementation, since the layout of the laboratory was not suitable for the group work foreseen for the second cycle. The teacher consulted with the administration to ensure that the library could be included in the activities, and the layout in the library was made suitable for group works before the activities. The availability of an additional place appropriate for group works at the school made a positive contribution to the implementation process in this cycle. On the other hand, the layout of the laboratory was more appropriate for carrying out the activities in the first cycle. Additionally, the layout of the activity learning environment was important for *the number of the students* in the classroom. The number of students should be sufficient to ensure collaboration during the activities but it should not be more crowded, which makes the management of the problem-solving process more difficult.

The robots were the other technical tools in the learning environment of the problem-solving activities. The students were able to give concrete expression to their solutions during the activities by redesigning these tools. For example, a group designed their robot as a refreshing hat that could be used in hot weather. Therefore, these tools facilitated the ill-structured problem-solving process in the current study with their flexible structure. However, not all robot kits on the market offer these opportunities to students. These packages, which come with ready-made robots, an inherent lock-in mechanism and closed hardware or software, do not give learners the flexibility to assemble them in their own way (Alimisis, Alimisi, Loukatos, & Zoulias, 2019). Additionally, the number of such tools was also crucial for the problem-solving activities, because the number of the groups can highly exceed the robot kits that are provided. Therefore, the ratio of the number of the robot kits and the participants should be planned accordingly before the activities (Theodosi & Deli, 2017). In the current study, the number of kits was determined according to the number of groups in both cycles. This arrangement therefore allowed the implementation process to move forward without any problem about the number of the robot kits.

The variety of materials and resources needed for the activities was not limited to technical resources. Teaching aids such as informative videos and images could be used to give details to the students about the use of tools and techniques, as well as printed materials such as paper-based sketches, worksheets, and printouts (Alimisis et al., 2019). In the current study, an *activity sheet* was used to provide students a pathway for the ill-structured problem-solving process in both cycles. Other paper-based materials, an activity rules sheet and a reminder worksheet for the robot pieces, were used in the second cycle. In fact, the reminder of robot pieces emerged as a necessity in the first cycle and an interactive slideshow was prepared as a teaching aid to remind students of the robot pieces. The reason for the use of printed material instead of this tool in the second cycle was the absence of smart boards in the school where the second cycle was carried out, as opposed to the first cycle.

Additionally, design tools such as scissors, glue, silicon, and so on have traditionally been used to hand-make works in such activities (Alimisis et al., 2019). These tools were identified as stationery materials in the current study and were utilized in the production phase of the activities to ease the problem-solving process of the students. Specifically they became an enabler of the problem-solving process by providing a simulation of the problem statement or by becoming a part of the solution during the problem-solving process. In addition, the method of delivery of these materials to students was another enabling factor. Specifically, a lot-based strategy for distribution of these stationery materials had a positive impact on the process of problem-solving activities.

5.1.2 Primary Challenges of the Robotic Problem Solving Activities

Instructional Challenges

Group Work Problems

While working with a group typically encouraged problem-solving in the collaborative learning settings, the problems faced in groups or among groups could suffice to expose the challenging aspect of this approach during the activity process. These situations existed as *group conflict* and *disengagement* from the groups during the implementation process, according to the findings. These group problems were mostly reported by the participants during the interviews in the first activities, and the frequency of their expressions specifically on intragroup issues gradually decreased towards the final activities. The potential reason for this uneven distribution and its declining trend towards the end could be explained by the students' familiarization with the collaborative problem-solving process. In addition to the reduction in problems as a result of this familiarization, it was also thought that the students may have developed their methods of dealing with these problems. Some of the solution strategies, such as consensus and collaboration, differ from others in that they were collaborative strategies and provided us insights about how the students used them in the process to overcome challenging issues in group dynamics.

Group conflicts usually resulted in resentment, negligence of a division of labor, and mobbing among members during the implementation process. The mobbing among members was specifically revealed in the reflection papers, activity drawings, and evaluation forms of the students filled out at the end of the activities. The common feature of these three data sources was that they asked students to examine their interactions with others in the group. In addition, the students brought these forms to the researcher in sealed envelopes so that they were sure that they would not be seen by other friends. This result, reflecting the mobbing in groups, arrived at using only these data sources and with no supporting results in the literature, revealed the importance of these forms in which students could express themselves more comfortably in order to discover undesirable interactions in the collaborative learning environments.

In contrast to mobbing, other group conflicts in the current study were consistent with the findings in the literature. Lee, Huh, and Reigeluth (2015) generally experienced three types of group conflicts in their research design. One of them was the task conflict defined as knowledge-building negotiations of group members, which had a positive effect on students' learning. On the other hand, the relation conflicts based on individual attributes and feelings of the members about other members influenced the level of learning negatively (As cited in Grant & Tamim, 2019). Additionally, it was natural to have a negative influence of patterns of involvement that were more equal when solving ill-structured tasks than structured ones. These inequities might reduce the quality of discussions in groups and group performance in collaborative learning environments (Kapur & Kinzer, 2007). As a result, there would be group members who wanted to simply do more and members who were not interested in what other members were doing. Therefore, task sharing and the division of labor in such collaborative environments should be encouraged as expressed by Üçgül (2012). In fact, task sharing and division of labor arose spontaneously in the first cycle of implementation in the current study. In contrast to the first cycle, however, it was provided in a systematic way in the second cycle. However, the negligence of the division of labor still existed during the activities in both practices. Therefore, the procedure used for task sharing and division of the labor in this study might need to be upgraded to provide a fully collaborative working environment for the students during the problem-solving process.

As a result of disagreements or other problems, some of the group members appeared to be leaving their groups. This *disengagement from group* was another challenging factor of the group work component of the current activities. The students leaving the groups were interested in other groups' work or stationery materials in the classroom. The teacher and the researcher made great efforts to get these students back into their groups but it was not always possible to achieve a complete solution for this problem. Peer pressure might be the reason for this impossibility. According to Fonteijn and Dolmans (2019), peer pressure on conformity would discourage opposition, reduce the benefits of diversity and could lead to polarization of the group. In addition, the differences between the members of the group could give rise to temporary group conflicts. It could therefore be difficult for group members to reach an agreement. In such cases, students need support on how to explain their reasons, how to be open-minded, and how to compromise when necessary (Ma & Williams, 2013) in collaborative problem-solving processes.

In addition to intragroup problems, some of the students had challenges with other groups during the activity time. These intergroup issues were about *the competitive interactions* in which the students felt in a state of comparison with other groups. In fact, it was a surprising result since all the current activities are based on collaborative – and not competitive – instructional approaches, which were mostly seen in extracurricular activities. According to this challenge, some of the students were exposed to this feeling since they thought they fell back from others during the problem-solving process. They therefore demoralized very quickly and experienced a lack of willingness to continue the activity process. In another study, this competitive environment between the groups was perceived by some of the students as discouraging since the other teams could see their fare during the activity process, while others thought that they were more motivated by ranking in a competitive environment (Zhang & Fang, 2019). This positive effect did not appear in the current study. On the other hand, the limited time of the activities might be the underlying reason for these challenging competitive interactions. The fact that some groups finished their work earlier in the phases of the activity might have lead other groups to the perception that they could not catch up with others.

Lack of Readiness

The importance of prior knowledge and possession of the required skills for the activities was discussed among the enablers of the problem-solving activities. Additionally, the deficiency of these issues was identified as a challenge in the findings. According to findings on *the pre-requisite deficiency*, a student who did not have enough prior knowledge or/and required skill level may experience several problems during the problem solving process. In addition to prior knowledge on the relevant subjects of the activities, some of these problems resulted from the knowledge base on the subjects developed over the previous years. For instance, the activities could not begin immediately during the implementation of the second cycle, since the teacher had to teach several subjects that had been missing from the previous year. This demonstrated the negative effects of the deficiencies of the previous year's knowledge on students' problem-solving process during the activities.

The lack of required skills – such as problem-solving, working collaboratively, programming, and use of stationery materials – made the activity process challenging. These findings of the current study were consistent with other research in the literature. According to Ma and Williams (2013), the absence of strategies to deal with an ill-structured problem was one of the biggest challenges for students. Additionally, students' lack of planning on how to build robots and use attachments on them resulted in difficulties about the design of robots. Previous experience therefore became crucial for students to manage their skills and overcome the barriers for meaningful learning in the activities (Gürkanlı, 2018).

Skill development is highly related to the age of the children. As such, the ages of the participants were discussed here in terms of the required skills of the problem-solving activities. A longitudinal research (length 6 years) on the use of robots in school settings indicated one of the underlying reasons for its success was the diversity of the student population (Karp & Maloney, 2013). Another report attributed the rationale of this success to the manufacturer's production of robotic kits for different age groups (Yang, Liu, & Chen, 2020). However, according to McNerney (2004), most students in elementary schools were not ready to program robots in the traditional manner which refers to typing codes into computers until 10-14 years old. In the current study, the students used only visual algorithm elements to program their robots instead of coding them with programming scripts.

Additionally, their ages ranged from 10 to 12 years old, which is a proper age range for visual programming. Therefore, the lack of skills needed for programming robots cannot be linked to the age of the student participants. However, some of the remaining skill deficiency, in particular the use of stationery materials (in design) might be related to the development of the students' hand skills. In fact, they were not able to use some of the operative stationery materials such as a utility knife during the activities and they needed to get help from the teacher or researcher while using these materials. More courses and activities to develop such skills should therefore be included in the curriculum of elementary schools.

The readiness of the students was also linked to *misconceptions* on the subject of corresponding courses (ITS and Science). In detail, the students typically had misconceptions about the programming subject in the ITS Course and the subject of friction force in the Science Course during the problem-solving activities. Additionally, the fishbone branches in the activity sheet could erroneously be filled in with the results of problems instead of causes by some students. The distribution of the data among the activities indicated that these misconceptions were only reported by the participants during the interviews of the first two activities. This might be an indicator that misconceptions could be remedied by students' experience during the implementation process. As indicated in another study, working with groups in a collaborative environment was more productive than individuals to generate ideas and insights, and more effective in terms of confronting and discussing the misconceptions (Kapur & Kinzer, 2007). The collaborative solution strategies used by students in the current study could be used for the elimination of the misconceptions during the problem-solving process. However, it might be important to fix them before the implementation for a smooth activity process in which the students solved ill-structured problems with educational robots.

Misconceptions as a challenging factor for similar activities were identified in other research. Panayiotou and Eteokleous-Grigoriou (2017) reported the common misconceptions of fifth grade students on the subject of light as an obstacle to achieving the objectives of the subject. According to Papadakis and Orfanakis

(2017), novice programmers frequently experienced confusions involving topics such as basic programming terms and other programming constructs (Veselovská & Mayerová, 2017). However, students were able to overcome these misconceptions as they built self-awareness by researching and transferring their ideas to solving problems with each other in a learning environment that encourages professional development (Hong et al., 2011). In another way, preparatory exercises aimed at training learners for robotic education could be used to discuss misconceptions (Komis et al., 2017). Therefore, students could progress without experiencing failure caused by misconceptions and the lack of integration of pre-knowledge into the learning experience (Chen, 2010).

Additionally, *low success level* had a detrimental effect on the problem-solving process. The students who had a low success level in related courses (ITS, Science) and other courses (Linguistic, Art) performed less than others during the activities. This underlined the multidisciplinary structure of the activities in close relationship with both relevant courses and others. The positive side of this structure was that the activities could be used to build an educational atmosphere in which expertise and abilities come from a wide variety of fields. However, the pre-requisites from these fields should be taken into account carefully and the deficiency in these fields should be fixed before the ill-structured problem-solving activities.

Time

The duration and *the schedule* of the activities were considered challenging factors, according to the findings. Students who did not finish their work at the end of the activity often complained about the inadequacy of the duration of the activities. The problem was mostly faced at the beginning of the implementation process, when the student did not have enough time management experience with the activities. On the other hand, *the schedule* of the activities was described as an obstacle for the later activities of the implementation. In detail, the students complained about the schedule of the activities since they lasted during Ramadan, when some of the students were fasting. This shows the importance of cultural elements such as

Ramadan for the process of the activities. Apart from this general cultural element, there was a decrease in attendance of the students towards the end of the semester. This was a general situation in which the students began to participate less in all courses but accordingly in the activities towards the end of the semester.

The problems with *the schedule* of the activities were unique challenges for the implementation of the current study. However, the problems concerning the *duration of the activities* were reported by several researchers in the literature. According to Ma and Williams (2013), iterative processes in the activities that were required to be completed within a short period of time pushed the student participants to work under pressure. As a result, time constraints became the greatest challenge of activities with a heavy workload (Mindetbay, Bokhove, & Woollard, 2019) for the students. The workload within the time constraints of robotic activities could be reduced by using robotic tools that are easy to use and learn (Gürkanlı, 2018). In addition, the workload might mostly relate to problem-solving itself since the students generally needed a longer period of time to solve ill-defined problems. As indicated in other studies, most of the time was spent on reflecting on options for solutions, the selection of these solutions during problem-solving (Chetty, 2015a), and errors in the process (Shim, Kwon, & Lee, 2017). The use of the trial-error strategy to overcome programming errors on the robot was also another time-consuming aspect of the activities (Mosley & Kline, 2004) as well as the design of the robots (Ching et al., 2019) at the end of the activities.

In addition to being a challenging component of the activities for the students, the time-consuming nature of the activities was also difficult for the instructors, according to the literature. For instance, technical support from outside the learning environment was typically not available due to time constraints. Additionally, working alone was not sufficient to overcome the technical problems and led to pressure for the instructors during such activities (Leoste & Heidmets, 2020). In the current study, the researchers were highly involved in the activities and helped the instructor with both technical and other difficulties. As a result, there was no issue with the length of the activities that influenced the instructor during the implementation process of the problem-solving activities.

The other learning and instructional challenges of the activities were *goal orientation*, *lack of motivation*, and *external challenges,* according to the findings. In detail, some students appeared to lose their focus in two ways during the activities. In one of these ways, the distracting nature of the stationery materials expanded the students' interest from the focus of the activities. These materials should therefore be carefully chosen before the activities, and their distribution should be arranged based on a lot method at the beginning of the design phase of the activities. In contrast to expanding shifts, the absence of turning back during the activities, and existence of solutions close to the attention of the students narrowed their focus during the problem-solving process. In fact, some algorithms on the activity sheets which students drew at the beginning of the activity were different from the algorithms on the robots as a result of the solution. It could be an indicator of the activities that were sufficiently flexible to return to other phases. However, some students were unable to experience this flexibility. Often, because of the time consuming aspect of the activities, they could not turn back during the problem-solving process.

Other obstacles to the activities concerned *the motivation* of students during the implementation process. Emotional routers including the prejudgment that the solution would not be used in reality affected students' motivation negatively. In addition, some of the students were not willing to perform their tasks, which were organized on the basis of the division of labor into groups for the same reason. The lack of motivation for these issues indicated that special attention needs to be paid to the use of the students' solutions for the ill-structured problems. With an exhibition held at school, students can share their solutions with other students, managers and even robotic industry experts. This might help students see that what they do is important and boost their motivation toward completion of the activities. Moreover, some students expressed an emotional effect at the introduction video and the scenario of the activities. It did not preclude them from finding solutions in those activities, but showed that we need to be very careful about the quality of the videos and the scenarios chosen.

The external challenges of the activities were mostly related to the administrative issues of the schools. The extra tasks of the administration might prevent the teacher from carrying out the activities. In the current study, the researcher continued the remaining part of the activity instead of the teacher, who left the classroom for about ten or fifteen minutes for these administrative issues. Under normal circumstances, however, this could lead a variety of problems. Another administrative challenge for the activities was an obligatory student exchange between classes. This change brought several problems such as the students of the other class were not trained enough to perform in the activities and the groups were dispersed because of the exchange. These types of problems underlined the need for a flexible schedule of activities. This flexible program might be used against external challenges that arise during the activities so they could be postponed for some time.

Logistic Challenges

Resource Problems

In addition to the learning and instructional challenges, the activities have faced various *logistical challenges* during the implementation process. Among these challenges, the problems about *the resources* were related to *stationery materials*, *robots,* and *the infrastructure of the laboratory*. Similarly, Jedrinović, Ferk Savec and Rugelj (2018) identified technical and material based problems as one of the main barriers of the integration of ICT into the learning process of the students. In a narrower context, the lack of resources resulted in an imbalance in the number of groups and resources such as robots, which was a major challenge in the implementation of robotic activities (Theodosi & Deli, 2017). In the current research, such problems were not experienced since the implementation processes in both cycles began with enough robot kits. However, additional robot pieces were reported to be kept ready in the environment due to the damaged components of the robots. The problems with the damaged robot parts were discussed below.

Breakdown of the robots' pieces was an important problem during the problem-solving activities. Most of the disruptions occurred with the wires of the robot kits. In detail, when students were mounting their robots at the beginning of the activities. These wires were specifically those attaching the wheels to the mainboard. Since no additional kits were available in the activity environment, these parts were fixed with a soldering machine, but this procedure caused quite a waste of time and the students who encountered this problem were demoralized during the activity process. This finding was consistent with the findings of the literature. According to Gürkanlı (2018), unsuccessful behaviors such as being hasty to connect wires and short-circuits due to lack of attention to connecting points demoralized students in practice. Therefore, false wiring while using the microcontrollers on the robots was one of the commonly faced challenges in robotic learning environments. Additionally, the students were often dealing with the robots' inconsistency in performance since the set-up, power level, and battery level of robots changes from day to day (Ma & Williams, 2013). This indicated the value of the consistent performance of robot kits in activity environments. The consistency of robot kits was also important for the students in the current study. During new activities, they often wanted to work on robot kits they were familiar with from previous activities.

Infrastructural problems were also among the logistic challenges of the activities. In detail, the problems of connection between robots and computers were addressed during the implementation of the second cycle. According to the findings, these problems were articulated only by the instructor, but the researcher also observed them several times during the activities in second cycle. The explanation behind the presence of this issue for only the second cycle was that the laboratory infrastructure in this cycle consisted of computers with different hardware because of economic grounds as opposed to the laboratory in the first cycle. Due to the variety of hardware, some computers were only able to be attached to certain robot kits in the laboratory. The problem was therefore resolved in this laboratory by distributing the same robot kit to each student group in all activities. This challenge emphasized the importance of the consistent infrastructure of the learning environment for activities in which the students solved ill-structured problems using educational robots.

In addition to these technical challenges, the problems relating to *stationery materials* emerged as another major resource challenge in the current study. The distribution of these materials at random was the main part of the problem. This problem was then resolved by a lot-based method of distribution. In addition, the students used these materials to design their solutions, but all of them had to be available in the classroom during the previous phases of their activities. Accordingly, students were able to examine these materials even in the previous phases in which they had started to solve ill-structured problem. In contrast to this finding, Gürkanlı (2018) suggested that the learning environment of robotic activities should contain only robotic construction materials to help educators to keep the environment in order. However, this recommendation was not applicable to activities in which ill-structured problems are solved, since it might prevent students from freely producing solutions to those problems.

Learning Environment

Working collaboratively as an experience in problem-solving activities was a novelty for students in the current study. Specifically, this experience provided them the opportunity to solve problems in groups, to collaborate and discuss with group mates, and to walk around and communicate with other groups. The construction and maintenance of such flexible learning environments brought several *environmental challenges.* For example, *the noise level* was very high during the activities. Although several precautions have been taken, such as the related activity rule, or warnings to overtalkative students in the activities, the noise problem was not fully resolved during the implementation process. However, the distribution of data on this issue showed that the complaints about this problem were more common during the initial activities and reduced throughout the implementation process.

In addition to student noise, the main tools of the activities (robots) were creating sounds by bumping into other robots and objects during the activities. The noise level in the classroom might therefore be very high and it was very difficult for the instructors to calm down, according to Chetty (2017). This expression coincided with one of the findings of the current study. According to the students in the current study, *the voice of the buzzer* on the robot was very high and annoying for them. This finding showed us an issue that addresses the production of educational robots. Using quieter products in their production might make their use easy by reducing the noise level of the learning environment. A similar permanent source of noise was described as computer fans and an air conditioner which can generate a constant background voice in the learning environment of the activities by Connell, Edwards, Hramiak, Rhoades and Stanley (2015). However, these sources were not identified in the current study.

Additionally, *the classroom structure* might be inappropriate for problem-solving activities as in the second cycle of the current study. The general layouts of computer laboratories were introduced as “around the edge of the room, against the wall, across the room in rows, islands and mobile equipment” by Connell and Edwards (2014, p.64). In the first cycle of the implementation of the current study, the design of the laboratory was an "island," and collaborative work of the groups was conducted smoothly in this suitable learning environment. However, when it was another one "in a row across the room" as in the second cycle, some groups could not sufficiently coalesce during the problem-solving process. The first phases of the activities was therefore conducted in the school library, which was a more suitable environment. However, the activities were not continued in this suitable environment for the remaining phases since there was a need to access the computers in the laboratory in order to program the robots during them.

The high number of the students in the classroom and *the violation of the rules* were other challenges to the activities associated with only one class of implementation in the second cycle. This class, which consisted of only male students, was more crowded than any other class of practice. In addition, the students in this crowded environment tended to break the rules of the activity that were introduced at the beginning of implementation. As stated in another study by Sisman, Kucuk and

Yaman (2020), crowded classrooms might not be very convenient for the effective implementation of robotic activities. When it was crowded and the number of instructors was not sufficient, it caused problems in the classroom where the instructors could not interfere with any unwanted situation on time (Üçgül, 2012).

5.1.3 Primary Characteristics of the Robotic Problem Solving Activities

Structural Characteristics

Complexity

Attempts to achieve the best learning outcomes with a combination of various technologies could increase the complexity of the learning environments (Mogos et al., 2018). However, an optimum level of complexity in activities was indicated as one of the requirements for students to establish and maintain a shared understanding (Kamga et al., 2017). The complexity of tasks and students' mental development should be correlated in order to reach this optimum level (Felicia & Sharif, 2014). The activities of the current study were prepared on the basis of a number of analyses and after obtaining experts' opinions in the fields of IT and science to meet these criteria. In addition, some indicators of the level of complexity of the activities emerged during the implementation process. These indicators may assist instructional designers in the structure of such activities.

The perceived difficulty of the whole activity, phases and *the troubles* were the complexity indicators which require extra effort from students to successfully solve the ill-structured problems. The indicators of simplicity, on the other hand, were *perceived simplicity* (getting easy and getting used to) and *ease of ill-structured problem* during the implementation process. Not all of these indicators, but some of them were consistent with the results of other studies. For instance, according to Shim, Kwon and Lee, (2017), it was relatively difficult for the students to create the robot's route and configure it to carry out the task of the operation. This referred to the perceived difficulty of design and programming issues in the activities as in the current study. Similarly, according to Gyebi et al. (2017), the programming task required the learning of programming concepts that introduces a different level of complexity for students. When the background knowledge and experience of students is not sufficient, robot building is very difficult for them (Ching et al., 2019). However, in the current study, the students did not specifically report the complexity of the robot construction, although the pieces of the robot kits were given separately to them for the first time during these activities. The explanation for this result might be that the used robot kit included relatively few pieces that could be considered appropriate for the age group of students. According to Gürkanlı (2018), adapting activities to students' age requires a range of alignment from physical parts of the robot to the software complexity of these tools. For instance, effective programming software should be free from syntactic rules that make programming languages difficult for children (McNerney, 2004).

The feature of drag-and-drop in visual programming editors might be perfect for learners from all age groups since they provide the opportunity to experiment with programming structures simply joining these constructs without heavy knowledge of any programming languages (Papadakis & Orfanakis, 2017) and are sufficient tools to learn algorithms as a learning outcome in an interesting and easy way (Alshehri, 2019; Pachidis et al., 2019). Accordingly, using a visual editor in the current study might ease the programming of robots for the students while they are solving ill-structured problems during the activities. In addition to the visual programming that is necessary for the age group of students, the experience they gained from the initial activities simplified the remaining activities for them during the implementation process.

Equipment

Each activity group was expected to solve the ill-structured problem and develop a product at the end of the activity as the solution to this problem in the current study. The equipment used for this solution consisted of unique materials referred to as *stationery, robotic,* and *auxiliary materials* for the activities. These materials were discussed here with the literature in order to simplify similar activities later on. In fact, the investment in such activities can actually guide the schools towards the effective use of these activities (Barreto & Benitti, 2012). In particular, in order to develop a useful curriculum, researchers must pay attention to supporting learning facilities like the tools available in the activities (Latip & Hardinata, 2020). However, a detailed identification of these tools was presented by a limited number of studies in the literature such as the study by Bellas, Salgado, Blanco and Duro (2019), and Balogh and Petrovič (2020). The equipment used for the current activities was outlined below.

The robotic materials including actuators (motor, led, buzzer, and speaker), sensors (analog and digital sensors), and other parts (mainboard, battery, connection cable) were one of the necessary pieces of equipment for the activities. Students were asked about the necessary actuators and sensors at the analyzing stage of the ill-structured problem. Based on their responses on the activity sheet, the preferred actuators in the activities were listed from the most to the least needed one as buzzer, dc-motor, led, and speaker, respectively. The selected analog sensors were ordered as temperature, proximity, and light sensors. Additionally, in terms of digital sensors, touch sensors were needed more than optical sensors during the problem solving process of the activities.

The stationery materials of the activities were categorized as essential (cardboard, paper, felt), operational (glue, scissors, paint), and complementary (flashlight, latch, box), and they were used to design and develop the product or simulate the problem statement during the activities. In addition to these functions, the students were strongly motivated by these materials during the problem-solving process.

Structure Level and Dynamicity

The natural process of the activities began with an ill-structured problem as a starting point. The students then followed a problem-solving process in a collaborative environment. As an end point, the solution of the problem was a product including the programming and the design of robots. While this general structure was the same for all the activities, they were ordered on the basis of the structure level of their problem scenario during the implementation process. Therefore, as in activity scenarios, several structural characteristics emerged related to the *activity structure level*.

The unifying factors in the general structure of the activities were the resources (problem scenario, robotic materials, stationery materials, the video), and constraints (duration of activity, perception of the students) of the activities. In contrast, the context of the problem scenario, possibilities for variations in design and programming were *the diversifiers* of this structure level of the activities in the current study. In another study, the heterogeneity of the groups including cognitive and demographic diversity improved the group performance in terms of quality information and learning outcomes (Fonteijn & Dolmans, 2019). This diversity enabled groups to build context-related knowledge (Sing, 1999). Therefore, the diversifiers of the structure level of the current activities might contribute the knowledge of students about the context of the ill-structured problems.

According to Jonassen (2004), the problems generally differ in their stability or dynamicity. The ill-structured problems tend to be more dynamic, which means that the problem solver must adapt to the understanding of the problem and make the necessary changes on the solution, since the conditions of the problem change and the old solutions may no longer be feasible. In the current study, the solutions of groups differed constantly in the activity process and these differences indicate *the dynamicity* of the activities. Specifically, the dynamicity in activities was stimulated by the process of creating a solution proposal, changing the solution proposals, and the use of resources in an interchangeable manner. On the other hand, the elimination of proposals for solutions, the inadequacy of resources, the lack of solution suggestions, and interactions between groups were the factors that reduce the dynamicity of the activities.

These dynamicity variables often arise naturally in activities, and the legitimacy of competing alternatives referred to the extent of the number of acceptable options in the problem space (Hung, 2019). These options could not be examined during the problem-solving process in the current study. However, the number of proposals for solutions for each activity was identified with the help of the related part of the activity sheets. According to the corresponding findings, students tended to come up with more solution proposals at the beginning of the implementation process in both cycles, and this amount declined towards the end of implementation. The underlying reason for this finding could indicate the novelty effect of the activities for students. The students might want to find the right solution by providing more proposals to ill-structured problems at the beginning of the implementation process, when they did not have enough experience. On the other hand, they might start to offer clearer proposals and eliminate some of the others that were not feasible for them by gaining more experience in the ill-structured problem-solving process towards the end of the implementation. This showed that the process of generating solution proposals shortened and turned into a stricter structure towards the end of the implementation process of problem-solving activities.

The domain of these dynamic activities emerged from the findings of the current study as another structural characteristic of them. The related fields of Science, ITS and others (Linguistics, Arts, Engineering) indicated the multidisciplinary aspect of the activities. In addition, activities were identified as firmly linked to the daily-life context, which ensured the proximity of selected ill-structured problems to real-life situations as one of their characteristics.

Instructional Features

Transfer

The findings of the current study indicated the transferable aspect of the activities as one of their significant instructional characteristics. According to the participants, the transfer of activities was possible on a daily, professional, and educational basis, as well as on other projects. According to the general scope of the literature, the transfer of leanings in the problem-solving process might take place in two ways. In near-transfer situations, the learner can solve new problems using the same context and level of complexity as the learned one. Far transfer, on the other hand, provides the ability to solve new problems in a similar context to those used in the learning environment and the different complexity that is increased by adding new factors (Jonassen, 2010). On the basis of these characteristics, the explanations of the participants of the current study regarding the transfer of activities mostly referred to the far type of transfer. However, there was also transfer of learning within the activities and between the activities which was not reported by the participants. This near transfer could be traced to students' expertise in activities and the reduction in the perceived level of difficulty or guidance needed throughout the implementation process. In addition to these indicators, the use of classroom learning prior to the implementation, learning in classroom activities, and learning in other activities indicated three ways for this near transfer in the current activities as stated by Catlin (2017).

Traditional formal educational settings do not always provide the transfer of acquired knowledge for problem-solving. New educational approaches are therefore crucial to helping learners to use information and skills to meet challenges (Bransford & Stein, 1993). The learning settings that activate learners, in contrast to traditional methods, facilitate the understanding, retention and transfer of learning from class to practice (Tani et al., 2017). Problem-based activities can build a bridge to allow the transfer of knowledge and skills to real life (Koh, 2015) as the problem-solving process involves a series of serious steps from problem formulation to generalization and transfer of this process to a wide variety of situations (González & Muñoz-Repiso, 2017; Eguchi, 2017; Li, 2020). Therefore, the range of transfer areas found in the current study might be considered as a contribution of these activities which provide successful transfer paths for student participants into the literature.

Credibility

The expressions made by the participants about the purpose of the activities, explanations about them and the evaluable aspects of the activities constituted the credibility of the activities in the current study. According to Sullivan (2017), if a pedagogical approach focuses on promoting the creativity of students who take a non-evaluative stance, the center of the stage might be a long-term activity or activity series that aims to explore, learn and develop without the burden of evaluation, as exists in the current study. Additionally, the goals of the activities explored in the current study might assist instructional designers in the creation of activities. Specifically, the goals of the activities were found to be twofold. In one of these, the general goals of the activities were identified as using educational robots, solving problems, and developing a product. Additionally, the activity-based goals were to upgrade robots (for the first activity), protect people (for second and third activity), and protect the environment (for the last activity). These goals might be useful for practitioners to use in non-evaluative learning environments as well as others to put the objectives of the instruction and do the evaluation of learning as a part of the problem-solving activities.

Activities were also identified as explainable for classmates, teachers, and others not related to activities such as family members with design-related and technical aspects. These findings were consistent with the findings in the literature. According to Eguchi (2017), students presented their robotic creations to the public as classmates, teachers, and families. They worked on their explanations by evaluating and summarizing their activity process in order to reach the final form of the presentation. In the current study, each group presented their solutions to the teacher and other friends at the end of each activity. According to Chalmers and Nason (2017), with whole class presentations, the students could see other alternative solution approaches, products, strengths, and weakness and analyze the advantages and disadvantages of different alternatives (González et al., 2020). In addition to these presentations, the students provided explanations of the activities during the focus group meetings in the current study. These explanations were mostly design-based, in which the solution to the problem was expressed by the emphasis on design issues. Additionally, the technical explanations were also considerable. In those technical explanations, the students tended to explain the technical aspect of the activities such as the sensors they used, or details of programming, more than other issues. According to Veselovská, Kubincová and Mayerová (2020), the explanations given by the students in their presentation differ on the basis of their grade levels. While the third grade students reported robotic models with only fictional behaviors, the fourth graders tended to attribute imaginative features, in addition to fictional features (density and laser sensors), to their robotic models. This might be consistent with a finding in the current study that both the technical and the design explanations of the students were based on their solutions and functions of that solution in the current study.

The activities also provided the teacher with a general review of the learning status of the students, since they cover all subjects of the semester. In this general assessment, activity sheets, reflection papers, and peer review forms might be used for the evaluation of students as well as the observation of the entire activity process. According to Whittier and Robinson (2007), the use of robots gives the teacher the opportunity to observe the progress of the students more concurrently in a process that is otherwise very slow and difficult. In addition, systematic observation provides a formative evaluation of the intervention to document the progress of learners on the outcomes of the activities (Roussou & Rangoussi, 2019). However, such a systematic observation was not utilized in the current study. Instead, the effects of the activities on the students were asked to the teacher in detail through semi-structured interviews after each activity. As indicated, this method might be used to reach open responses articulating the views concerning the effectiveness of the activities for their evaluation (Papadakis & Orfanakis, 2017). In addition, achievement tests were used to examine the learning outcomes of the activities on corresponding subjects in the Science and ITS Courses during the implementation of the current problem-solving activities.

Reports and reflections enable an authentic assessment of the results by providing a detailed description of the lessons learned (Walter & Verner, 2020). In the current study, reflection papers provided a source of information to track student insight into the activity process. Students could easily write a problematic situation about the activities in these forms. For example, several students wrote problems in their groups on these forms. As a result, the problems experienced could receive immediate intervention. In addition, the group dynamics were also examined with the help of peer evaluation forms during the implementation process. The most important feature that worked here was that these documents were secretly collected in envelopes from the students. Students could therefore easily express their thoughts about the group mates and other friends on these tools. According to Benitti and Spolaôr (2017), the generation of standardized assessment tools is needed to ensure the quality of robot-based learning environments. The tools used in current research, which were very close to students' insights, might therefore take their place in the assessment process of problem-solving activities in which the educational robots are used to solve ill-structured problems.

Practice

Activities in the current study provided students hands-on practice opportunities with educational robots in the resolution of an ill-structured problem in which the context was enriched by science subjects. According to Gyebi et al. (2017), practice during the activities improves the quality of teaching and learning with the active participation of students. This participation is a key focus of creativity in solving problems, and students are strongly motivated to enhance their learning (Varnado, 2005). When the students participate actively in their learning process, they learn to do, work, and share with others (Chetty, 2017). In the current study, working with others made the distribution of tasks compulsory for the groups. The division of labor was therefore used as a technique for the distribution of the tasks that were specifically identified as filling the activity sheet, programming robots, and designing. During this distribution, the instructor might need to ensure that all group members contribute to the tasks of others in an appropriate way during the problem-solving process.

Through this active collaboration, active learning approaches become the heart of activities that focus on learning rather than teaching. Students therefore have a new role to play in building knowledge (Araújo, Moallem, Hung, & Dabbagh, 2019). The teaching strategies should help students to develop and sustain their self-learning and exploration spirit in this learning environment (Bédard, Moallem, Hung, & Dabbagh, 2019). Applying knowledge to solve problems can be an effective method of developing and sustaining that spirit since, according to Tan (2003), an iterative problem-solving process requires the contextualization and application of information in a particular circumstance in which the learners rephrase, paraphrase, and reveal new knowledge. Similarly, in the current study, students were required to apply their knowledge on a number of subjects in order to solve ill-structured problems. As in other activities, these activities provided platforms for learners to practice key programming subjects (Castledine & Chalmers, 2011; Chetty, 2015; Shim, Kwon, & Lee, 2017; Gyebi, Hanheide, & Cielniak, 2017), practice problem-solving, work on fine-motor skills and eye–hand coordination (Bers, Flannery, Kazakoff, & Sullivan, 2014), and apply concepts from relevant subjects to solve real-life problems (Ching et al., 2019).

Contributions to Learner

Skill Development

Developing 21st-century skills such as enhancing technological literacy, developing learning skills by enhancing critical thinking, creative thinking, collaboration, communication, and improving life skills such as flexibility, teamwork, and leadership are the new generation's necessary requirements (Job & Saeed, 2016). The use of robots in education has the potential to meet these life-long skill requirements (Khanlari, 2016). For instance, according to the findings, problem-solving activities in the current study have contributed to *non-technical skills* such as soft skills and computational thinking skills and more *technical skills* such as ICT (Information and Communication Technology) and design skills of the students.

The development of *soft skills* during activities increased students' sensitivity to others. In detail, the insights the student participants gained such as helpfulness, respect for others, and awareness of people with disabilities were some of the contributions of problem-solving activities that can be used in the education of values. In addition, the development of collaboration and communication with others were the other contributions of these activities on students' soft skills. Some of these findings were in line with the literature. According to Truglio, Marocco, Miglino, Ponticorvo and Rubinacci (2019), collaborative activities were powerful learning environments that promote social reactions. They provide the opportunity to work in teams by enabling the improvement of social relations between students in the classroom. Therefore, the development of communication skills (Eguchi, 2014; Eguchi, 2016; Ángela et al., 2017) and team and collaboration skills (Karp & Maloney, 2013; Toh, Causo, Tzuo, Chen, Yeo, 2016; Eguchi, 2017) among the social skills (Üçgül, 2013; Felicia & Sharif, 2014) were the findings of the other studies that reported the contribution of activities designed with educational robots in different educational settings.

In one of these educational settings, Xenos, Yiannoutsou, Grizioti, Kynigos and Nikitopoulou (2017) conducted research to explore the potential of educational robotics as part of the school curriculum. The results of the study indicated that the integration of these tools has a positive effect on student learning. Generally, they developed problem-solving skills that help students understand the meaning of how things work in real-life situations. More specifically, the implementation of robotic technology in curricula enhanced and developed higher-order thinking skills and students' ability to solve complex problems (Blanchard et al., 2010). As indicated in these studies, the problem-solving skills of the participants were developed during the activities in which students programmed robots to solve ill-structured problems in the current study. These problem-solving skills were categorized under (CT) computational thinking skills as well as others such as autonomous learning (debugging) and algorithmic thinking skills in this study. In another study, the activities were found helpful for participants to develop CT skills in particular for problem-solving, algorithm building and debugging in a game model that used a visually programmed robotic agent for users (Kazimoglu et al., 2012). Further CT skills including abstraction, generalization, modularity, and decomposition were developed quite successfully with other activities. Among these skills, the most difficult skills to gain were perceived by the students as abstraction and decomposition (Atmatzidou & Demetriadis, 2014).

In addition, the current activities contributed to the development of more technical skills such as ICT and design skills, based on the findings. In particular, students had the opportunity to improve their robotic skills, defined as construction and programming of robots, during these problem-solving activities. Additionally, students used a visual programming editor to build their programs with flowcharts to solve problems with robots in their activities. According to Chetty (2015a), these visual programming platforms allowed students to deal with real-world robot problems and develop their dynamic programming skills in a language-independent environment. As a result, they found the chance to easily acquire the requisite programming skills with visual programming software (Ersoy, Madran, & Gülbahar, 2011) and understood basic principles of syntax-based programming languages with a syntax based editor in upper grades (Huei, 2014). In the current study, a visual programming editor was used, selected especially according to the level of development of students. Since this editor also provided programming for robots with a syntax-based language, this aspect might be tested in older classes to see the continuity of results.

During the activities, the design skills of the students – a technical skill – were also developed, based on the findings. This improvement in design skills, specifically hand and art skills, might be the results of the tangible aspect of the current problem-solving activities, as hands-on activities are specific learning environments that encourage students to build design skills (Schleter & Biegalski, 2015) and develop motor skills (Bers et al., 2014). The additional skills identified as the contribution of educational robotic literature were scientific creativity skills (Cavaş & Kesercioğlu, 2012), scientific inquiry skills (Jomento-cruz, 2010), and scientific process skills (Koç Şenol & Büyük, 2015) in STEM based research. These science-related skill developments cannot, however, be supported by the findings of the current study.

Learning Outcome

The learning outcomes of the activities also fell within the scope of the current study. In fact, participants reported on learning outcomes in related courses (ITS and Science) and other courses (Linguistics, Arts, Social Sciences and Mathematics) after the implementation of problem-solving activities. Specifically, the programming learnings (use of editors, menus in editors) and algorithm (function of algorithm shapes, use of loop structure) in the ITS Course and in the subjects of the Science Course (heat, light, disruptive natural events, strength, and friction) were the main outcomes of the activities. Other studies also pointed to the potential impact on similar outcomes. For example, Mohammed and Saeed (2016) reported that a robotic training program improved the performance of students in science. In addition, Barker and Ansorge (2007) introduced an elementary science and technology curriculum for an after-school program. Results of the experimental study revealed that students had a significantly higher academic score on science and technology concepts in the robotic intervention group. On the other hand, an educational robotic program, enhanced with STEM concepts, did not affect the science gain of students compared to the regular curriculum in another study conducted by Jomento-cruz (2010).

These reported results also coincided with the results of a measurement applied in the current study. In detail, the results of the applied tests indicated that a statistically positive change occurred in the unplugged algorithm test scores of students who participated in activities in the second cycle. However, this change was not statistically significant for the students in the first cycle. Similarly, there was a positive change in the student scores of the science achievement test after they participated in the activities of the second cycle. However, this significant change was not seen in the first cycle. The level of prior knowledge could form the basis for these conflicting results, as at the beginning of the activities students had fewer prior knowledge at second school. This result might show us that the problem-solving activities were more effective for low-level students in the subjects of both courses (ITS and Science) because while it made a significant difference in the groups with lower scores, this difference was not significant in the group of students with higher scores. Furthermore, in both cycles, the students' grade levels were different. As the time of implementation of the activities moved away from the time of coverage of these subjects, the range of student test scores increased according to the results. Therefore, these activities might be more effective to recall the subjects for students who studied these subjects long ago. In addition, these activities took place in the second cycle of the implementation classes according to gender discrimination so that this result could be related to the gender of the students.

In addition to skills development and learning outcomes, the activities also enhanced the motivation of students as a further contribution. In detail, the interest of students on both courses (ITS and Science) and on activities were increased during the implementation process. This was more evident for the students who had low level of interest toward the courses at the beginning of the implementation process. The majority of these students were girls and the activities specifically removed the lack of interest these students had toward the technology throughout the implementation process. Additionally, all the students from both genders specifically gained the feeling of success during the activities by solving ill-structured problems. This feeling engaged them into the activity process and motivated them to perform similar activities.

The activities also contributed to the professional development of the teacher in a variety of ways. In one of them, experience in activities increased the interest of the teacher in research, such as conducting similar activities with the integration of other courses rather than science. Additionally, he wanted to use different robot kits in those activities. A tendency to change the instructional method used was also seen as another contribution of the activities for the teacher. Accordingly, the future plans of the instruction would include more problem-solving approaches where the students are highly active, and the resources used effectively. The communication of the teacher with students was also improved during the implementation process. According to this contribution, the activities helped him to get used to the new working environment by establishing closer relationships with the students.

5.1.4 Guideline for the Implementation of Collaborative Problem Solving Activities with Educational Robots

In the results section of the current study, recommendations for the guideline of the activities were compiled in five headings (motivation, preparation, cushioning, communication, learning outcomes and settings), based on codes and categories developed for previous research questions. However, it was not easy to predict the effects of these headings on activities since they were not generated for the implementation process of the activities. Accordingly, the guideline presented in this part of the report was therefore combined with the implementation process. In this process, each activity started with the phase of introduction and ended with an evaluation phase. However, the preparation and closure phases also emerged corresponding to all activities during the implementation process. All of these phases and the main components of the guideline are shown in Figure 5-1.

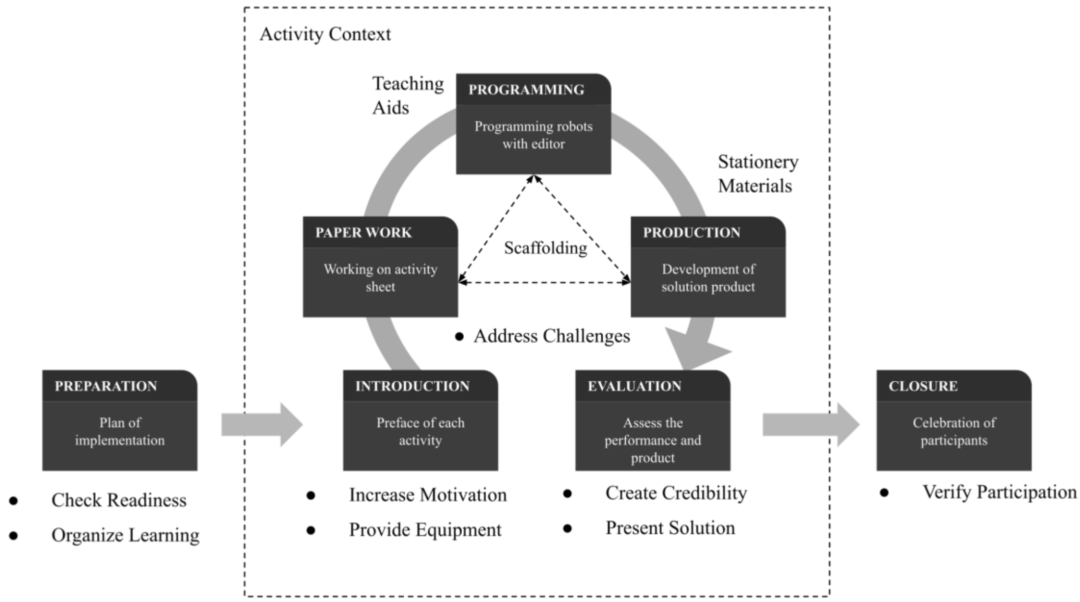

Figure 5-1 Guideline Components in Activity Process

Figure 5-1 shows that the activities began with the *preparation phase* of the implementation process. In this part, the guideline demands that the teacher might check readiness for the activities and organize the learning in the activities. It is extremely important because the necessary decisions are taken in this phase on the activities and it lays the organization for all activities in the implementation process. Therefore, while making these decisions, the instructor should not hesitate to use certain means such as pre-tests. In different ways, the next five phases of implementation are the iterative processes for each activity. Among them, an increase in student motivation is expected to be part of the introduction phase. In this part of the activity the students also begin the problem-solving process. In other words, the group of students who have been motivated to solve the problem begins to create their problem space for the ill-structured problem in the activities.

According to guidance, the students follow the next three phases, specifically *paper work, programming, and production phases* iteratively. Protecting this three-fold structure is therefore very important for the problem-solving process. In order to explain the iterative structure of these phases further, the students are expected to fill the activity sheet to follow a path through the ill-structured problem solving process. In the programming and production phases, the students may turn back to the activity sheet and make use of it. Furthermore, the groups starting to develop their products may frequently need to return to the programming phase to change their programs on the robots. The guideline shows that in this iterative process scaffolding should be provided for the students to overcome the various challenges of the activities.

The credibility of the activities should be ensured through the use of several tools during the *evaluation phase.* The activity sheet, reflection paper, and peer evaluation forms can be made ready for the assessment of the outcomes. Additionally, the presentation of the solutions to others at the end of each activity can be used for the credibility of the activities. These presentations may provide the students the feeling of success, which is very important for their motivation toward the activities. The certificate that serves as a verification tool for the participation of the students in the activities can be another source for this feeling. The guideline suggests that this certificate can be given to the students in the *closure phase* of the activities.

The main components of the guideline and their details were discussed with other attempts in the literature. In one of those studies, Mosley and Kline (2004) (1) identified a list of recommendations for a task-based service course in which university students worked in groups to construct and program robots to complete four exercises. The details of these exercises indicated that the most sophisticated task was to build a robotic grip that would capture soda cans. Unfortunately, the paper did not contain any information on the level of structure of these tasks. Additionally, Williams et al. (2007) (2) reported six principles for developing and implementing robotic programs. The research was carried out on a robotic camp that was prepared for middle school students and consisted of a mixture of hands-on activities of the whole and small groups that provided experiments with physics concepts.

A further study was conducted by Üçgül (2012) (3) to reveal the design principles of educational robotic training camps. For this purpose, two robotic camps were organized with elementary school students. These two studies contributed to the literature by investigating the robotic activities in non-school educational settings. In contrast, Kamga et al. (2017) (4) introduced the design requirements for robotic education activities that support a collaborative problem-solving approach when integrated into a typical school curriculum. The results of the study were based solely on the literature review. It is therefore necessary to confirm these design requirements in the context of the intervention of robotic activities in the CPS learning environment. The design requirements of the educational robotics in the school environment were also explored by Gürkanlı (2018) (5) from the educators' perspective. However, the implications of the study indicated the importance of the investigation of such requirements from the perspective of the students. Additionally, the participating educators were all in private schools, which was another limitation of the study. The researcher expressed that different needs may exist in governmental schools.

Although all these studies differed in some aspect from the current study, the general purpose of all was to organize learning environments using educational robots. Therefore, looking together at the components of the guideline and the results of these studies can be an effective method both for the feasibility of the guideline and the discovery of the differences with other studies. Table 5.1 presents the guideline with components of the current study. Numbers next to the components indicate the relevant research in the literature.

Table 5.1 Guideline Components and Details with Relevant Literature

Activity Phase	Guideline Component & Details
Preparation	**Check Readiness** o Grade level (3, 5) o Check pre-knowledge (2, 3) o Look for needed skills (2, 4, 5) o Remove misconceptions o Readiness of teacher (2) o Control infrastructure (1) **Organize Learning** o Number of students (1) o Number of equipment (1, 3) o Maintain the activity structure o Provide substitute teacher (3) o Form the groups (1, 3, 4)
Introduction	**Increase Motivation** o Use technology (5) o Use an introduction video o Encourage collaboration (3) **Provide Equipment** o Keep resources readily accessible (1, 3, 5)
Paper Work-Programming-Production	**Scaffolding** o Use activity sheet o Guide students (3) o Encourage peer guidance (3) o Provide teaching aids (in programming) (2, 3, 5) **Address Common Challenges** o Prevent noise o Overcome group problems o Distribute stationery materials (in design)

Table 5.1 (cont'd)

Evaluation	**Create Credibility** ○ Take goals ○ Use tools (Activity sheet, reflection paper, peer evaluation form) **Present Solutions** ○ Guarantee success feeling ○ Admit technical and design-based explanations (2)
Closure	**Verify Participation** • Provide certificate

1. Preparation Phase

1.1. Check Readiness

Grade level: The students' grade level is important for the robotic learning environments since there are no robot kits suitable for all age groups (Gürkanlı, 2018). The grade level of the participants should therefore be clearly defined as they are all at the same level in robotic camps (Üçgül, 2012). It will be the same in the school context, so that the choice of the grade level for the implementation becomes a crucial issue for the problem-solving activities in which students solve ill-structured problems using educational robots. The participants should not be too young at low cognitive stages, nor should they be in upper classes with barriers such as high school tests.

Check Pre-knowledge: The knowledge baseline from the related fields (ITS and Science) of the activities should be checked prior to the implementation process of the problem-solving activities. An appropriate assessment tool can be used to test whether students have sufficient knowledge of pre-requisite subjects in both courses. Subjects are follows:

- ITS Course: Knowledge of robot pieces, flowcharts, and algorithms
- Science Course: Force, temperature, sun rays, natural disasters, environment, electricity, sound, and distance

Students are given the opportunity to practice the mathematics and science knowledge they have learned in schools when robotic camps are ready to solve complex problems (Üçgül, 2012). If the students have different levels of content knowledge, they may need different activities in robotic programs (Williams et al., 2007). Hence it is important for participants in problem-solving activities to have a close baseline knowledge in order to carry out the activities in which they solve ill-structured problems with educational robots properly. Furthermore, removing gaps in prior knowledge for the activities will help them during the activity process.

Look for Needed Skills: The skills needed for the activities include collaborative work, programming, problem-solving, and design skills. The deficiency of these skills is one of the predictors of the lack of readiness. Students therefore need to acquire these skills in advance of their activities. According to Williams et al. (2007), although limited problem-solving skills can work well on structured robotic tasks, but different tasks (such as ill-structured problems in the current study) may benefit from different levels of capabilities. In addition, students are needed to use adjustable robotic tools with regard to the size of the embodiment elements, input / output connections and electronic components. The motor skills of the students are therefore important for the implementation of the activities (Gürkanlı, 2018).

Remove Misconceptions: Misconceptions about previous learning are another barrier to student readiness to work on ill-structured problems. The misconceptions can be linked to the pre-requisite knowledge or/and knowledge needed to carry out the activities. These misconceptions are follows:

- Knowledge base: Force and friction, natural disasters (science subjects), or name of robot pieces (ITS subject)
- Others: Filling the fishbone on the activity sheet, and knowledge of disability groups

The removal of these misconceptions before the activities is crucial in order to reach sufficient readiness for the activities. All of them should be carefully checked in advance of the implementation process. This finding of the guideline is one of the unique contributions of this research since misconceptions were not defined in guidelines of previous studies provided for the use of robots in different educational settings.

Readiness of Teacher: In addition to students' readiness, the instructor's readiness may also have an impact on the implementation process of the activities since he/she needs specific knowledge and skills to guide students through all phases of the activities. According to Williams et al. (2007), facilitators' lack of scientific inquiry skills has affected learning of students in the activities. Similarly, the teacher's inadequate design skills limited his contribution to the activities during the development of products in the current study. Therefore, all elements that affect the readiness of the teacher should be eliminated before the activities in order to carry them out properly.

Control Infrastructure: The infrastructure of the learning environment has a positive or negative effect on the whole process of implementation. For example, a learning environment with mobile tables and laptops offered an opportunity to reconfigure the room to create some open space for students (Mosley & Kline, 2004). Therefore, students can test their robots comfortably. There was no problem with the open spaces of the laboratory in the current study. However, because of the noise in the learning environment, some of the students needed to go to another room to record their voice on the robots.

In addition, the laboratory was not appropriate for group work in the second cycle of the current study. Another place in this school was used for the paper work phase. Besides these layout problems, the computers that were used had different hardware and operating systems which can cause various technical problems such as connection problems in the learning environment. Therefore, the infrastructure of the laboratory should be controlled for such technical and layout problems in order to be ready for the implementation of the activities.

1.2.Organize Learning

Number of students: Activities should be conducted in a classroom that is not crowded but also with a sufficient number of students to provide a collaborative learning environment. In situations where students are unable to continue their activities, an adequate number of students are becoming more and more important to continue the process of collaborative problem-solving activities. This inadequacy of students for activities is in conflict with one of the results of the literature, which showed that the small class size of robotic laboratory tasks is the most feasible for such environments (Mosley & Kline, 2004).

Number of Equipment: As each group in the activity needs its own equipment, it is important to decide on the number of robot kits before integrating them into the class (Mosley & Kline, 2004). Üçgül (2012) identifies the necessary set of equipment as robot kit, resource package (extra robot parts), and computer. The researcher also advised the preparation of extra robot sets and battery packs in the guideline of the robotic camps. Additional robot kits are also suggested to be prepared before the implementation process in the current study guideline, as the durability of these kits is not very good. The soldering machine can also be used to fix breakdowns of the robotic components during the problem-solving activities. The stationery materials used during the production phase of the activities are another necessary equipment for the activities. The guideline indicated that all equipment (Robotics, Stationery and Auxiliary Materials) of problem-solving activities should be prepared by considering the number of students involved in the activities.

Maintain Activity Structure: The general structure of the problem-solving activities was determined by taking into account the framework of the present study. Specifically, constructivism and constructionism shed light on the activities that the students engaged in in the learning process by doing, experiencing, and producing a product during the activities. This production process is based on an ill-structured problem-solving process in which students work collaboratively with their group mates. This environment of collaboration within the activities was created by considering the framework of CPS (Collaborative Problem Solving). The entire resulting structure was found as highly motivating for the students. Especially iterative phases in it (paper work, programming, and design) were seen as a source of entertainment during the implementation process. Therefore, this guideline advises that the structure of the activity process should be maintained during the implementation of the problem-solving activities.

Provide Substitute Teacher: Administrative tasks (as an external challenge) may interrupt the activity process during the implementation process. The activities should therefore be carried out with a substitute teacher. If these tasks are carried out before or after the activities, the need for the substitute will not exist anymore. However, some technical problems may still be present during the activities as internal challenges. Therefore, Üçgül (2012) advised a person with technical competence to overcome these challenges. In addition, according to him, one science instructor can be ready for scientific activities and discussions during the activities.

Form the Groups: In the current study the groups were composed of a total of three and four students. Groups with four students were preferred only when additional students were left in the classroom after the three-member groups were formed. Both are acceptable for the activities, but in the case of groups with three, if one student doesn't come to school that day, two students had to perform the activities. This means an increase in the workload for the remaining students in the group. For this reason, it may be more appropriate for groups to be formed of four in order to carry out activities without problems of workload. This number of group members overlaps with another recommendation in a research study conducted by Mosley and Kline (2004). Other research indicates that three member groups are advised and four members are also found acceptable for robotic camp activities (Üçgül, 2012). It is also considered that small teams for groups of 3 to 7 students to meet collaborative requirements in robotic learning environments are needed by Kamga et al. (2017).

In addition to the number of students, systematic work sharing and division of labor can be effective against intragroup problems (group conflicts, disengagement, or mobbing) during the implementation of the problem-solving activities. Accordingly, the division should be arranged for each student to have duties at any time during the activities as advised by Üçgül (2012). These duties are identified by the students as operating the robot, working on design, and observing (Mosley & Kline, 2004). Similarly, they are filling the activity sheet, programming the robot, and designing the robot with stationery materials in the problem-solving activities of the current study.

2. Introduction Phase

2.1. Increase Motivation

Use Technology: The great interest of students in technology can be used to motivate them at the beginning of the problem-solving activities. In addition, the series of activities can be aligned with this interest as the activity of the robot factory, which has the main focus on the technology (robots) itself, can be used at the beginning of the implementation since visually attractive robots enhance the students' active involvement in the robotic activities (Gürkanlı, 2018).

Use Introduction Video: An introduction video produced in conjunction with the problem scenario of the activities motivates the students for the activities. The students react with great interest to this video, and the teacher has found an opportunity to engage in an ice-breaking discussion of the problem scenario with the help of this video. It should therefore be used to attract the students' interest toward the problem itself easily at the beginning of each activity. However, it may involve upsetting content for the students in some activities. Therefore, these negative emotional effects should be avoided while preparing this video.

Encourage Collaboration: Collaboration in group work is an important catalyst for student motivation during the problem-solving activities. However, the level of motivation may decrease for some tasks (filling activity sheet / programming) in group work as they are not found to be as attractive as the design of materials by students. These tasks should therefore be encouraged to work collaboratively in groups in the introduction phase.

According to Üçgül (2012), this collaboration in a small group work environment could enhance the social interaction of the students. Interaction between groups could be enhanced by borrowing robotic pieces, exchanging knowledge as well as competition between groups. In contrast, the findings of the current study indicated that the competitive interactions between the groups could be of the challenges of problem-solving process in a cooperative learning environment. Competitions between groups were mostly seen as races to finish the phases earlier and as a result the group usually felt demoralized during the activities. Therefore, these competitive interactions between groups should be removed from the activity environments.

2.2. Provide Equipment

Keep Resources Readily Accessible: The resources of the activities (robotics, stationery, and auxiliary materials) should be prepared in advance of the problem-solving activities. First, the activity sheet should be printed before each activity because it contains different problem scenarios for each activity. Additionally, the robot kits should be checked for possible problems and to make sure it is not running out of battery. It should be noted that the students will use these robotic materials during the programming phase as well as stationery materials during the production phase. While it is highly recommended to provide these resources to students in the associated phase of the activity, they should be able to look at these materials whenever they want, such as in the paper work phase when creating the problem solutions.

Mosley and Kline (2004) suggested that all equipment should be transported and checked in the learning environment prior to the start of the learning activity. Power shortages, battery chargers, and memory shortages are key technological issues during robotic activities. It is therefore beneficial to support each group with a resource package containing extra resources in the learning environment (Üçgül, 2012).

3. Paper Work-Programming-Production Phases

3.1. Scaffolding

Use Activity Sheet: The activity sheet was used to provide students with a pathway to the ill-structured problem-solving process during the implementation process. It includes parts, starting with the presentation of the problem scenario. In reality, when watching the introduction video in the previous stage, the students begin to create the problem space. However, with this portion of the activity sheet, they transform it into a clearer one as here they encounter the real ill-structured problem statement. Additionally, with the last section on this sheet, they have the opportunity to create their algorithms to move on to the programming stage. Students can often turn back to this activity sheet during the programming and production phases and look at their notes, such as solution proposals or algorithms. This activity sheet can therefore assist students from the start of the activity to the end of it.

Guide Students: The instructors' main duty is to scaffold students during the problem-solving process. According to Üçgül (2012), they should track the progress of students in detail and give them the right amount of help at the right time. As in the current study, the instructors should direct the activity process, help the students, control the group work and give them feedback when it is needed. The level of instructor guidance is expected to fade out throughout the implementation process since the students get accustomed to the problem-solving process and have experience on several challenges in the activity process.

Encourage Peer Guidance: The students are also guided by the group mates during the problem-solving activities. Usually, when they have troubles, they get help from their peers and share their ideas with others. Collaboration and consensus, as one of the indicators of effective communication between group mates and the use of peer guidance during activities, have been used to address these troubles. According to Üçgül (2012), these social outcomes can be encouraged with less involved instructors and with a possible less managed learning environment. Accordingly, the use of these strategies should therefore be encouraged during the problem-solving activities.

Provide Teaching Aids: Just-in-time resources, such as tutorials and examples, should be integrated into activities to support the investigation process and promote content knowledge. In addition, similar resources can provide the concepts and principles that students need to construct and program robots (Williams et al., 2007). Learning stations can be used to promote these resources during the activities (Üçgül, 2012). The visibility of these guide and assistance resources is crucial in the learning environments (Gürkanlı, 2018). Accordingly, an interactive slide, which is presented on smart board to help students on most confusing topics such as the name and functions of robotic pieces might be beneficial during the activities. If an interactive presentation tool is not provided in the learning environment, a worksheet may be prepared for groups to solve problems with the recall of confusing subjects.

3.2. Address Common Challenges

Prevent Noise: The noise as a result of group works is one of the important challenges of the problem-solving activities. It is very closely linked to the interactions of students in groups and other groups. Moreover, the voice of technological devices such as the buzzer of the robot could be another source of this challenge. In order to prevent this contextual problem, a rule should be put into the prescriptions of the activities with other activity rules. Additionally, various warnings should be announced to the students during the activities.

Overcome Group Problems: The intragroup problems are enough to disrupt the positive climate and the effects of collaborative learning environments of the problem-solving activities. These problems have mostly arisen as conflicts in groups, negligence of duty, disengagement from group, and mobbing between group members. Groups should be monitored on an ongoing basis against these group problems and, when such problems are noticed, they should be resolved. In addition, the groups might be encouraged to prepare their own group contracts including all group problems before the activities. These contracts may be visited by the students during the problem-solving process, when they have such group problems.

Distribute Stationery Materials: The distribution of the stationery materials in the production phase is another major problematic issue during the problem-solving activities. During the distribution of these materials to students, as well as other resources, a method based on lot should definitely be preferred rather than random based distribution.

4. Evaluation Phase

4.1. Create Credibility

Take Goals: The problem-solving activities have general (problem-solving, developing product, use of educational robots) and specific activity-based goals (upgrade robots, protect people, and protect the environment). These goals can be used in the assessment of the students' outcomes from the activities.

Use Tools: In the assessment process, the activity sheets, reflection papers, and peer evaluation forms that will be made ready before the activities may also be utilized at the end of the problem-solving activities.

4.2. Present solutions

Guarantee Success Feeling: Activities inspire students by providing them with feelings of success, since they have solved a problem as a result of their activities. Moreover, they develop a hands-on product as a solution to an ill-structured problem during the activities. This concrete aspect of the activities may promote satisfaction to the students. In some cases, however, students have not been able to solve the problem and develop a product at the end of the activity. It should not be forgotten in those cases that even if the students do not produce solutions, they deserve this feeling as a result of their efforts in the activities.

Admit Explanations: The students should be encouraged to explain their solutions at the end of the problem-solving activities. These explanations may be design-related and/or the technical explanations for others. Regardless of their effectiveness, solutions to ill-structured problems should be presented to some/all people in the classroom or to others in the schools. According to Williams et al. (2007), such presentations contribute to the acquisition of content knowledge by students who have not been adequately engaged in the design challenges of the activities.

5. **Closure Phase**

5.1. Verify Participation

Provide Certificate: At the end of implementation it is advisable to carry out a closure program in which the teacher gives the participating students a certificate of attendance for the problem-solving activities. This certificate can be accepted as an award by students who deserve to be celebrated for their participation.

5.2 Implications and Suggestions for Practice

Although the findings of the current study are not appropriate for generalizations beyond the activities preprepared, the following recommendations are made to the stakeholders of the activities (instructional designers, teachers, students, school administrators, parents, and robot manufacturers) for the implementation of these or similar activities in similar contexts.

For instructional designers;

- The learning environment might be designed according to the students' collaborative interactions in problem-solving activities. In particular, the layout of the island laboratory appears to be more appropriate for group works comprising three or four members. The activities might therefore be carried out with this or similar layouts, which enable students to work together on ill-structured problem-solving activities as a group. In addition, a special area for testing robots in this layout might be provided because robots need to move around in some activity solutions.

- Emotional routers in the content of the problem scenarios or introduction videos of activities could adversely influence students' motivation during the problem-solving activities. In preparing these vital components of activities, great attention might be paid to the removal of these potential emotional routers.

- The goals of the problem-solving activities classified as general and activity-based may guide the development of non-evaluative learning environments, as well as others that need to assess the student learning outcomes by defining the objectives of problem-solving activities.

- The dynamic structure of problem-solving activities is closely linked to the solution proposal creation process of the students. In order to increase the level of this dynamic structure, the solution proposal creation process might be supported by some instructional methods during the activity process.

- Several intragroup problems may be encountered during the implementation of the problem-solving activities. Some of these problems, such as conflicts in groups, negligence of duty, disengagement from group, and mobbing between group members might be prevented by group contracts prepared by group members before the activities.

For teachers;

- The teachers may want to use the activities and guideline prepared for the implementation of the problem-solving activities. A short version of it (in Turkish) is therefore attached to Appendix U. In addition, a sample activity sheet and scenarios used in the activities can also be found in the appendices of the study. All these ready activities and related tools can be used during the implementation of the problem-solving activities in similar contexts.

- The motivation of the students is one of the most important enablers of the problem-solving activities. Specifically, the entertaining aspect of the activities, facilitative resources, and feeling of satisfaction might be used to motivate the students while they are solving ill-structured problems in activities.

- High level of readiness is required for the problem-solving activities in terms of both pre-requisites and previous instruction prior to activities. Students must reach this level of readiness in order to best take advantage of the activities.
- One of the major obstacles for the ill-structured problem solving activities is student misconceptions in previous instruction. Teachers may therefore be able to check and correct these misconceptions prior to implementation process.
- Teacher guidance is the most needed assistance for the students during the problem-solving process. Therefore, one should be very active during the activity process and take care of each group of students equally. Accordingly, effective communication with students is needed since they are expected to feel free to ask questions about their work.
- It is very difficult to observe in-group interactions during activities. Therefore, undesired interactions within the group could be identified using forms such as activity reflections and peer review provided to students after the problem-solving activities. In this way, problems that could grow within the group are predicted and prevented before the following activities.
- As disengagement from groups is a very common occurrence during the activities, the teacher who faces such challenges might prepare an environment in which such problems can be discussed between the members of the group and advise them to respect the opinions of group mates.
- Peer guidance is one of the key enablers of ill structured problem-solving activities. Therefore, students may be encouraged to be open to communication with other students, to reach consensus with others, and to work collaboratively with group mates during the problem-solving process.

- While students are performing their tasks during the problem-solving process in according with the division of labor that they established, some group members may not allow others to contribute to the tasks. In such cases, the teacher might encourage students to work according to the division of labor within their groups.
- Problem-solving activities are conveyed to families by the students in various ways. Therefore, the teacher might inform the parents about problem-solving activities in advance of the implementation process.

For school administrators and policy makers;

- The school administration might take these activities into account while setting the course schedule, so that the hours of the course could be set one after the other. In this way, the situation of students who cannot participate in activities between the course hours might be minimized as possible.
- A flexible schedule might be established for the problem-solving activities for possible external challenges such as mock exams. In addition, the administrative tasks for the teacher should not interrupt the activity process. These tasks might be given to the teacher outside the time of problem-solving activities.
- Some of the students may be demoralized with the idea that their solutions to ill-structured problems are not used in reality. These solutions can be brought together with other students, teachers, parents, and experts from different sectors with an exhibition at the school. Thus, students might get the impression that the solutions they find are worthwhile.
- The hand skills of the students are very important for the development of a product as the solution of the ill-structured problems during the activities. However, students may not be able to use some of the stationery materials during the production phase. Therefore, subjects that will improve these

skills might be included in the curriculum of the relevant elementary or middle school courses.

For robot manufacturers;

- Laboratories in educational environments may be equipped with computers with different hardware and software for economic reasons. Taking this into account, the robot industry should produce educational robots that can work smoothly with different operating systems and hardware.
- The robot industry might produce more durable and quieter robots, as broken robot parts are one of the greatest obstacles encountered during the implementation process of the problem-solving activities. Furthermore, because the activities are carried out with many groups in a collaborative environment and all the students are highly active in this environment, there will already be a noise problem. The sounds made by robot parts, such as buzzers, can make this environment even louder, so that quieter educational robots are needed in learning environments.

5.3 Implications and Suggestions for Further Research

- The current study has revealed guidelines for problem-solving activities in which middle school students solve ill-structured science problems with educational robots. However, they should be improved with further studies in order to develop an instructional design theory for such learning environments.
- The contributions of the problem-solving activities to the students were mostly determined by their own statements (rather than outcomes related to science and algorithmic achievement). These areas of contributions should be investigated by experimental studies to test whether or not there is a significant effect.

- Future research might use different robot kits in the problem-solving activities since some of the findings could be tool-based in the current study.
- Some of the findings of the study are concerning the visual programming used to program the robots during the problem-solving process of ill-structured problems. This programming platform was used as it is more suitable for the development of students. Further studies can be conducted with the same editor but using its syntax-based programming platform in higher grades.
- The effects of the problem-solving activities on academic achievement for science and algorithm were found different for two cycles of the implementation. As the grade levels were different for these two cycles, one of the potential reasons might be that these activities are more effective for recall of the subjects. Therefore, more studies might explore this possible reason. Another potential reason could also be gender discrimination in the form of second-school classrooms. The effects of the activities should therefore be examined by considering students' gender in future investigations.
- Two cycles of the implementation of problem-solving activities were carried out in different public school contexts in Turkey. One of these schools was a vocational school, while the other one was a middle school. There were both similar and different findings for these schools in this study. These findings can be compared with the findings of a future study conducted in a private school context.
- The ill-structured problems in the activities were created on the basis of subjects covered by the science course in the middle school curriculum. Further studies may be conducted with similar problems related to other courses, such as social science, in the same curriculum.

- During the problem-solving activities, the researcher played an active role like the teacher. In particular, he guided the students, answered their questions, and solve the faced problems during the implementation process. The future investigations can be done by isolating the researcher from the process of problem-solving activities to see the impact of researcher on the findings clearly.

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APPENDICES

A. Interview Protocol for Analysis of Current Status

Merhaba. Ben araştırma görevlisi Mustafa Güleç. Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü'nde doktora tez öğrencisiyim. Doktora tezim kapsamında araştırma konum Bilişim Teknolojileri ve Fen Bilgisi (Bilim Uygulamaları) Derslerinin Eğitsel Robotlu Problem Çözme Etkinlikleri ile Birleştirilmesidir. Sizinle bu odak toplantılarını gerçekleştirecek olmamın sebebi, çalışmanın başlangıcında elimizdeki imkanları, etkinliklerin gülü ve zayıf yönlerini, süreçte karşılaşılabilecek tehditleri araştırmak için bir analiz gerçekleştirmektir. İzninizle bu görüşmeyi kayıt altına almak istiyorum. Katıldığınız için teşekkür ederim.

QUESTIONS

Strengths

1) Çalışma kapsamında hazırlanacak olan etkinliklerin güçlü yönleri neler olabilir?

- Bu etkinlikleri derste kullanmak ne gibi avantajlar sağlayabilir?
- Bu etkinliklerle neler başarılabilir?
- Bu etkinlikleri diğer etkinliklere göre güçlü kılan özellikler neler olabilir?
- Etkinlikleri bu okulda uygulamanın sağlayacağı avantajlar neler olacaktır?
- Etkinlikleri bu öğrenci grubuyla uygulamanın sağlayacağı avantajlar neler olacaktır?

Weaknesses

1) Çalışma kapsamında hazırlanacak olan etkinliklerin zayıf yönleri neler olabilir?

- Bu etkinlikleri derste kullanmak ne gibi dezavantajlar ortaya çıkarabilir?
- Bu etkinliklerin başarısız yönleri neler olabilir?

- Etkinlikleri bu okulda uygulamanın dezavantajları neler olacaktır?
- Etkinlikleri bu öğrenci grubuyla uygulamanın oluşturacağı dezavantajlar neler olacaktır?

Opportunities

1) Çalışma kapsamında hazırlanacak olan etkinliklerle ilgili elimizdeki imkanlar nelerdir?

- Bu etkinlikler için okulun sağladığı olanaklar neler olacaktır?
- Bu etkinlikler için okul dışındaki çevrenin sağladığı olanaklar neler olacaktır?

Threats

1) Çalışma kapsamında hazırlanacak olan etkinliklerin uygulanma sürecinde hangi engellerle karşılaşılabilir?

- Bu etkinliklerin uygulanma sürecini olumsuz yönde etkileyecek faktörler nelerdir?
- Bu etkinliklerin uygulanma sürecine zarar verecek unsurlar nelerdir?

B. Interview Protocol for Suggestions of Teachers on Activities

Etkinliklerin Hazırlanması Görüşme Soruları

Öncelikle merhaba. Doktora tez çalışmam kapsamında "**BİLİŞİM TEKNOLOJİLERİ VE FEN BİLGİSİ (BİLİM UYGULAMALARI) DERSLERİNİN EĞİTSEL ROBOTLU PROBLEM ÇÖZME ETKİNLİKLERİ İLE BİRLEŞTİRİLMESİ"** konulu bir araştırma yapıyorum. İzninizle öncelikle bu çalışmanın içeriğinden biraz bahsetmek istiyorum. Çalışmanın genel amacı eğitsel robotlar yardımıyla Bilişim Teknolojileri ve Bilim Uygulamaları derslerini birleştiren problem çözme etkinlikleri geliştirmektir. Çalışmada Bilişim Teknolojileri ve Bilim Uygulamaları derslerinin içerikleri ile hazırlanmış bu etkinlik problemlerinin çözüm süreçleri detaylı bir şekilde incelenecektir. Bu incelemenin sonucunda etkinlere yönelik bir kılavuz oluşturulması planlanmaktadır. Eğitsel Robot olarak robotsan firmasının hazırlamış olduğu O-bot eğitsel robot kiti kullanılacaktır. Etkinlikler problem çözme basamaklarına göre tasarlanacaktır. Bu basamaklar çerçevesinde öğrenciler öncelikle, problemi tanımlayacaklar, ihtiyaç duyulan veriye ulaşacaklar, bu veriyi analiz edecekler, çözüm üretecekleler ve çözümü değerlendireceklerdir. Sizinle bu görüşmeyi gerçekleştirmemin nedeni ise daha önce bu eğitsel robot kitleri ile ilgili bir eğitim almış olmanızdır. Görüşme sırasındaki ilk soru geçmiş deneyiminizle ilgilidir. 2., 3., 4. ve 5. sorular bu çalışma sırasında hazırlanması planlanan etkinlikler ile ilgilidir. Kalan sorular ise uygulamanın yapılacağı okulda daha önce gerçekleştirilen analiz ile ortaya çıkmış konular üzerine olacaktır. Görüşmemiz yaklaşık olarak 25 dk sürecektir. İzninizle görüşmemizi kayıt altına almak istiyorum.

Katıldığınız için teşekkür ederim.

1) Öncelikle almış olduğunuz robotik eğitimi sonrasında derslerinizde eğitsel robot kitlerini kullandınız mı? Ne amaçla kulandınız? Açıklar mısınız lütfen?

Hayır ise 2. soruya geçebilirsiniz.

- Hangi konuda uygulama yaptınız? Neden bu konuyu seçtiniz? Açıklar mısınız?
- Uygulamanızı nasıl hazırladınız? Uygulamanın hazırlık sürecinden bahsedebilir misiniz? Bu hazırlık sürecinde nelere dikkat ettiniz?
- Etkinliğinizin uygulama sürecini anlatabilir misiniz? Uygulama sürecinde nelere dikkat ettiniz?
- Etkinliğinizin olumlu olduğunu düşündüğünüz yönleri neler?
- Etkinliğinizin olumsuz olduğunu düşündüğünüz yönleri neler?
- Etkinlik sürecinde hangi problemlerle karşılaştınız? Bu problemleri çözmek için hangi önlemleri aldınız veya çözümler ürettiniz?
- Bu süreci öğrencilerinizin gözünden değerlendirseniz neler söylersiniz? Öğrencileriniz bu etkinlik hakkındaki görüşleri nelerdi?

2) Şu anki 5.sınıf bilim uygulamaları ders müfredatındaki hangi konular ve/veya kazanımlar sizce eğitsel robotlarla hazırlanacak olan problem çözme etkinlikleri için uygundur? Neden? Açıklar mısınız?

3) Bu konularda öğrencilere yöneltilebilecek gerçek hayat ile ilişkili problem durumları neler olabilir?

4) Bu problem durumlarını hikayeleştirmek istesek nasıl bir senaryo oluşturulabilir? Bu senaryonun özellikleri neler olmalıdır? Örnek bir senaryo oluşturabilir misiniz?

5) Bu problem durumu etkinlik sırasında öğrencilere nasıl sunulmalı?

6) Bu etkinliklerin uygulama sürecinde sizce ne gibi sorunlarla karşılaşılabilir? Bu sorunların çözümü için önerileriniz nelerdir?

7) Öğrencileri bu etkinliklere motive edebilmek için neler yapılabilir?

8) Öğrencilerin etkinliklere konu olan fen bilgisi alanındaki hazırbulunuşluklarını yeterli düzeye getirebilmek için neler yapılabilir?

9) Bu etkinlikleri öğrencilerin bilişsel düzeylerine uygun hale getirmek için neler yapılmalıdır?

10) Etkinlik sürecinin uygulanmasıyla öğrencilere gelecek olan ekstra iş yükünü azaltmak için neler yapılabilir?

11) Ders süresinin yeterli olamaması durumunda neler yapılabilir?

12) Etkinliklerdeki öğrenme çıktıları sizce nasıl ölçülmelidir?

Eklemek istediğiniz bir şey var mı? Teşekkür ederim.

C. Interview Protocol for Students

Merhaba, ben araştırma görevlisi Mustafa Güleç. Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü'nde doktora programı öğrencisiyim. Doktora tezim kapsamında araştırma konum Bilişim Teknolojileri ve Fen Bilgisi (Bilim Uygulamaları) Derslerinin Eğitsel Robotlu Problem Çözme Etkinlikleri ile Birleştirilmesidir. Sizinle bu görüşmeyi gerçekleştirecek olmamın sebebi dersinizde kullanmış olduğunuz etkinliklerin özelliklerini, etkinlik sürecini kolaylaştıran ve zorlaştıran unsurları ve derse katkılarını araştırmaktır. İçten ve samimi cevaplarınızı duymak bana büyük bir mutluluk verecektir. Konuşmalarımız tamamen gizli tutulacak olup, üçüncü şahıslarla kesinlikle paylaşılmayacaktır. Ayrıca isminiz kesinlikle yazılı akademik belgelerde yer almayacaktır. İzninizle bu görüşmeyi ses kayıt cihazı ile kayıt altına almak istiyorum. Görüşme sırasında herhangi bir sorunuz olması durumunda, lütfen sorun. Görüşmemiz yaklaşık olarak 30 dk sürecektir.

Katıldığınız için çok teşekkür ederim.

Ürün Temelli Görüşme Protokolü (Öğrenci Grubu)

1. Bu derse bir arkadaşınızın katılamadığını düşünelim. Ona yardımcı olmak için yapmış olduğunuz "Robot Fabrikası Etkinliğini" ona nasıl anlatırsınız?
2. Robot Fabrikası etkinlik yaprağındaki problemi ilk gördüğünüzde neler düşündünüz? Bize anlatır mısınız?
    - Sizce bu problemde çözülmesi istenen neydi?
    - Bu problemi kendi cümlelerinizle nasıl tarif edersiniz?
3. Robot Fabrikası etkinlik yaprağındaki problemi çözmek için nelere ihtiyacınız oldu? Neden? Açıklar mısınız?
    - Bu problemi çözmek için daha öncesinde bilmeniz gerekenler nelerdi? Neden? Açıklar mısın?
    - Bu problemi çözmek için neler kullandınız? Açıklar mısın?
4. Robot Fabrikası etkinliğindeki problemi nasıl çözdünüz? Bize o çözümü anlatır mısınız?
    - Soruyu çözmek için nereden başladınız?
    - Soruyu çözmeye nasıl devam ettiniz?
    - Soru ile ilgili neden bu çözümü seçtiniz?
    - Soru ile ilgili bu çözümü nasıl tahmin ettiniz?

- Soruyu çözerken uygulamış olduğunuz adımlar doğru muydu? Herhangi bir hatayla karşılaştınız mı? Evetse, bu hatayı gidermek için ne yaptınız?

- Sizce bu sorunun başka çözüm yolları var mıydı? Evetse, bu çözüm yollarını neden kullanmadınız?

5. Sizce dersinizde kullandığınız robot fabrikası etkinliğin olumlu yönleri nelerdi? Neden? Açıklar mısınız?

   - Bu etkinliğin hoşunuza giden yönleri nelerdi?

6. Sizce robot fabrikası etkinliği sırasında işlerinizi kolaylaştıran şeyler nelerdi? Neden? Açıklar mısın?

   - Problemi çözerken etkinlik yaprağını nasıl kullandınız?

7. Sizce dersinizde kullandığınız robot fabrikası etkinliğinin olumsuz yönleri nelerdi? Neden? Açıklar mısın?

   - Bu etkinliğin hoşunuza gitmeyen yönleri nelerdi?

8. Sizce bu etkinlik sırasında işlerinizi zorlaştıran şeyler nelerdi? Neden? Açıklar mısın?

   - Sizi neler zorladı?

9. Dersinizde kullandığınız etkinliğin size nasıl bir katkısı olmuştur?

- Size neler öğretti? Neden? Nasıl?
- Konuyu öğrenmenize yardımcı olmuş mudur? Neden? Nasıl?
- Arkadaşlarınızla birlikte çalışmanıza yardımcı olmuş mudur? Neden? Nasıl?
- Algoritma konusunda nasıl bir katkı sağlamıştır?
- Fen bilgisi ile ilgili nasıl bir katkı sağlamıştır?

10. Bu etkinlikte öğrendiklerinizi sizce nerelerde kullanabilir siniz? Neden? Açıklar mısın?

- Başka bir problem çözerken bu etkinlik sizce nasıl işe yarar? Neden? Açıklar mısın?

D. Interview Protocol for Teacher

Merhaba. ben araştırma görevlisi Mustafa Güleç. Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü'nde doktora programı öğrencisiyim. Doktora tezim kapsamında araştırma konum Bilişim Teknolojileri ve Fen Bilgisi (Bilim Uygulamaları) Derslerinin Eğitsel Robotlu Problem Çözme Etkinlikleri ile Birleştirilmesidir. Sizinle bu görüşmeyi gerçekleştirecek olmamın sebebi dersinizde kullanmış olduğunuz etkinliklerin özelliklerini araştırmaktır. İçten ve samimi cevaplarınızı duymak bana büyük bir mutluluk verecektir. Konuşmalarımız tamamen gizli tutulacak olup, üçüncü şahıslarla kesinlikle paylaşılmayacaktır. Ayrıca isminiz kesinlikle yazılı akademik belgelerde yer almayacaktır. İzninizle bu görüşmeyi ses kayıt cihazı ile kayıt altına almak istiyorum. Görüşme sırasında herhangi bir sorunuz olması durumunda, lütfen sorun. Görüşmemiz yaklaşık olarak 60 dk sürecektir.

Etkinlik Özellikleri

1) Dersinizde kullandığınız problem çözme etkinliğini problemin yapılandırılmışlık seviyesi bakımından nasıl değerlendirirsiniz?

- Problemin çözümünde kullanılabilecek kurallar sınırlı sayıda mıydı? Neden? Açıklayabilir misiniz?
- Alternatif çözüm yolları hakkında ne düşüyorsunuz?

  Doğru cevap sayısı hakkında neler söylersiniz?
- Çözüm yolunun öngörülebilirliği (tahmin edilebilirliği) hakkında neler düşünüyorsunuz?
- Çözümün değerlendirilmesi için ne tür kriterler kullanılabilir? Neden? Açıklayabilir misiniz?
- Problemin yapılandırılmışlık seviyesi problemin çözümünü nasıl etkilemiş olabilir?

2) Dersinizde kullandığınız problem çözme etkinliğini problemin zorluk derecesi açısından nasıl değerlendirirsiniz?

- Çözümü için öğrencilerinizde bulunması gereken ön bilgi için neler söylersiniz?
- Çözüm için gerekli adımlar nelerdi? Bu adımların anlaşılırlığı hakkında neler söylersiniz?
- Çözüm sürecinde öğrencileriniz tarafından gerçekleştirilmesi gereken paralel süreçleri değerlendirebilir misiniz? Bu paralel süreçlerin karmaşıklığı hakkında ne düşünüyorsunuz?
- Etkinlikteki problemin zorluk derecesi problemin çözümünü nasıl etkilemiş olabilir? Neden?

3) Dersinizde kullandığınız problem çözme etkinliğini problemin dinamikliği açısından nasıl değerlendirirsiniz?

- Problem içerisindeki değişkenler arasında nasıl bir ilişki vardı?
- Faktörler arasındaki ilişki zamanla değişen bir ilişki miydi? Neden? Açıklar mısınız?
- Problemin dinamikliği problemin çözümünü nasıl etkilemiş olabilir?

4) Dersinizde kullandığınız problem çözme etkinliğinin ilişkili olduğu alanlar hakkında neler düşünüyorsunuz?

- Sizce bu alanlardan en çok ilişkili olduğu alan hangisidir? Neden? Açıklar mısınız?
- Sizce bu alanlardan en az ilişkili olduğu alan hangisidir? Neden? Açıklar mısınız?
- Bu alanlar problemin çözümünü nasıl etkilemiş olabilir?

5) Dersinizde kullandığınız problem çözme etkinliğinde kullandığınız problemin çözüm sürecini diğer problemle benzerlik açısından nasıl değerlendirirsiniz?

- Sizce başka problemlerle benzer olan yönleri nelerdir? Neden? Açıklar mısınız?
- Sizce çözüm sürecinde öğrencileriniz bu benzerlikten nasıl yaralandılar?

6) Dersinizde kullandığınız problem çözme etkinliğinde kullandığınız problemi neden-sonuç ilişkisi açısından değerlendirebilir misiniz?

- Sizce problemin içerisinde bir neden sonuç ilişkisi var mıydı? Neden? Açıklar mısınız?
- Çözüm sürecinde bu neden sonuç ilişkisini öğrencileriniz nasıl

kullandılar?

7) Dersinizde kullandığınız problem çözme etkinliğini öğrencilerinizi çözüme yönelten yardımcı soruların gerekliliği noktasında nasıl değerlendirirsiniz?

- Bu sorulardan bu etkinlikte yararlandınız mı? Neden?

  E: Hangi tip sorulardan yararlandınız? Neden? Açıklar mısınız?

  E: Çözüm sürecinde sizce öğrencileriniz bu sorulardan nasıl yararlandılar?

8) Dersinizde kullandığınız problem çözme etkinliğinde öğrencilerinizin ürettikleri savları (argümanları) nasıl değerlendirirsiniz?

- Çözüm sürecinde bu savları (argümanları) öğrencileriniz sizce nasıl kullandılar?

9) Dersinizde kullandığınız problem çözme etkinliğini öğrencilerinizin oluşturdukları modellemeler açısından nasıl değerlendirirsiniz? (Oluşturdukları tablolar, grafikler, kavram haritaları ya da algoritmalar)

- Çözüm sürecinde bu modellemeleri öğrencileriniz sizce nasıl kullandılar?

Kolaylaştırıcı ve Zorlaştırıcı Unsurlar

1) Dersinizde kullandığınız problem çözme etkinliğinin uygulama sürecini kolaylaştıran unsurlar nelerdir? Neden? Açıklar mısınız?

- Dersinizde kullandığınız problem çözme etkinliğinin uygulama sürecini olumlu yönde etkileyen faktörler nelerdir? Neden? Açıklar mısınız?

2) Dersinizde kullandığınız problem çözme etkinliğinin çalışan yönleri nelerdi? Neden? Açıklar mısınız?

3) Dersinizde kullandığınız problem çözme etkinliğinin uygulama sürecini zorlaştıran unsurlar nelerdir? Neden? Açıklar mısınız?

4) Dersinizde kullandığınız problem çözme etkinliğinin çalışmayan yönleri nelerdi? Neden? Açıklar mısınız?

5) Dersinizde kullandığınız problem çözme etkinliğinin geliştirilmesi gereken yönleri nelerdi? Neden? Açıklar mısınız?

6) Dersinizde kullandığınız problem çözme etkinliğini daha etkili hale getirebilmek için bu etkinlik üzerinde ne gibi değişiklikler yapılmalı? Neden? Açıklar mısınız?

Etkinliğin Katkıları

1) Dersinizde kullandığınız problem çözme etkinliğinin öğrencilerinize katkısı hakkında neler söylersiniz?

- Dersinizde kullandığınız problem çözme etkinliğini öğrencilerinizin ihtiyaçlarını karşılaması noktasında nasıl değerlendirirsiniz?
    - Konuyu öğrenmeleri noktasında ihtiyaçlarını karşılamış mıdır? Neden? Nasıl?
    - Problem çözme becerilerini geliştirme noktasında ihtiyaçlarını karşılamış mıdır? Neden? Nasıl?
    - Birlikte çalışmayı öğrenme noktasında ihtiyaçlarını karşılamış mıdır? Neden? Nasıl?
- Dersinizde kullandığınız problem çözme etkinliğinin öğrencilerinize yardımcı olduğunu düşündüğünüz yönleri nelerdir?
    - Konuyu öğrenmeleri noktasında yardımcı olmuş mudur? Neden? Nasıl?
    - Problem çözme becerilerini geliştirme noktasında yardımcı olmuş mudur? Neden? Nasıl?
    - Birlikte çalışmayı öğrenme noktasında yardımcı olmuş mudur? Neden? Nasıl?
- Dersinizde kullandığınız problem çözme etkinliğini öğrencilerinizi belirlediğiniz hedeflere ulaştırması noktasında nasıl değerlendirirsiniz?
    - Fen bilgisi alanındaki hedeflere ulaşma noktasında nasıl değerlendirirsiniz?
    - Bilişim teknolojileri alanındaki hedeflere ulaşma noktasında nasıl değerlendirirsiniz?
- Dersinizde kullandığınız problem çözme etkinliği öğrencilerinizi bilgi ve iletişim teknolojilerini kullanma noktasında nasıl etkilemiştir? Neden? Açıklar mısınız?
- Dersinizde kullandığınız problem çözme etkinliği öğrencilerinizin fen bilgisi dersine olan ilgisini nasıl etkilediğini düşünüyorsunuz? Neden? Açıklar mısınız?
- Dersinizde kullandığınız problem çözme etkinliği öğrencilerinizin bilişim teknolojileri dersine olan ilgisini nasıl etkilediğini düşünüyorsunuz? Neden? Açıklar mısınız?
- Dersinizde kullandığınız problem çözme etkinliği öğrencilerinizin motivasyonlarını nasıl etkilediğini düşünüyorsunuz? Neden? Açıklar mısınız?

- Dersinizde kullandığınız problem çözme etkinliğinin öğrencilerinizin algoritmik düşünme becerileri üzerine nasıl bir etkisi olduğunu düşünüyorsunuz? Neden, açıklar mısınız?
- Dersinizde kullandığınız problem çözme etkinliğinin öğrencilerinizin fen bilimleri dersindeki başarıları üzerine nasıl bir etkisi olduğunu düşünüyorsunuz? Neden, açıklar mısınız?

2) Dersinizde kullandığınız problem çözme etkinliğinin size sağladığı katkı hakkında ne düşünüyorsunuz?

- Dersinizde kullandığınız problem çözme etkinliğini ulaşmak istediğiniz eğitsel hedefler açısından ihtiyaçlarınızı ne ölçüde karşıladı?
- Dersinizde kullandığınız problem çözme etkinliği size mesleki anlamada nasıl bir katkı sağlamış olabilir?
- Dersinizde kullandığınız problem çözme etkinliği bilgi ve iletişim teknolojilerini kullanmanıza ne gibi bir katkı sağlamış olabilir?

- Dersinizde kullandığınız problem çözme etkinliği üzerinde bir şeyleri değiştirme şansınız olsa neleri değiştirirdiniz? Neden? Açıklar mısınız?

Probing Questions:

- Bu etkinliği etkinlik dışında kalan öğretim açısından değerlendirebilir misiniz? Bu etkinlik öncesi öğretimin etkinlik üzerindeki etkileri nelerdir?
- Bu etkinliğin uygulanma sürecini öğretmen rolü açısından değerlendirebilir misiniz? Sizin bu sürece etkiniz sizce nasıldı?
- Bu etkinliğin uygulanma sürecini öğrencileriniz açısından değerlendirebilir misiniz? Öğrencilerinizin rolü nasıldı? Öğrencilerinizin bu sürece etkisi sizce nasıldı?
- Bu etkinliğin uygulanma sürecinde eğitsel robotların kullanımını nasıl değerlendiriyorsunuz? Sizce eğitsel robotların etkinlik üzerindeki etkileri nelerdir? Açıklar mısınız?
- Bu etkinliğin uygulanma sürecinde eğitsel robotlar dışındaki kaynakların kullanımını değerlendirebilir misiniz? Bu kaynakların etkinlik üzerindeki etkileri nelerdir? Açıklar mısınız?

E. Ill-structured Problem Scenario Development Form

BİLİŞİM TEKNOLOJİLERİ VE BİLİM UYGULAMALARI DERSLERİNİ BİRLEŞTİREN EĞİTSEL ROBOTLU PROBLEM ÇÖZME ETKİNLİĞİ

Konu	İnsan ve Çevre	
Kazanımlar	**Fen Bilimleri** F5.6.2.1 F5.6.2.2 F5.6.2.3 5.11 5.12 5.20	**Bilişim Teknolojileri** BT.5.5.1.1 BT.5.5.1.2 BT.5.5.1.4 BT.5.5.1.5 BT.5.5.1.13-14-15-16 BT.5.5.2.2-3-5-7-8-9-10
Soru Cümlesi		
Senaryosu	GSP kovaları etrafa çok fazla mikrop saçıyor. Rahatsızlık veriyor. Acaba robotlar bu sorunda size nasıl yardımcı olur?	
Senaryo Sunumu	Video	
Etkinlik Adı	GSP toplayan robotlar	
Gerekli Araç Gereç	* Karton * Makarna * GSP	

F. Problem Scenario Evaluation Form

Problem Senaryosu Değerlendirme Formu

<table>
<tr><td colspan="7">ETKİNLİK NO: Lütfen etkinlik numarasını bu alana yazınız.</td></tr>
<tr><td colspan="2">Yargı Cümlesi</td><td colspan="5">Yargıya Katılma Durumu</td></tr>
<tr><td colspan="2">Genel</td><td>Tamamen Katılıyorum</td><td>Katılıyorum</td><td>Kararsızım</td><td>Katılmıyorum</td><td>Tamamen Katılmıyorum</td></tr>
<tr><td colspan="2">1. Problem senaryosu anlaşılır bir şekilde sunulmuştur.</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td colspan="2">2. Problem senaryosu belirtilen konu ile uyumludur.</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td colspan="2">3. Problem senaryosu öğrenci grubunun bilişsel seviyesine uygundur.</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td colspan="2">4. Problem senaryosu belirtilen öğrenme çıktıları için uygundur.</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td colspan="2">Yapılandırılmamış Problem Özellikleri</td><td colspan="5">Yargıya Katılma Durumu</td></tr>
<tr><td colspan="2">Problem senaryosuna göre…</td><td>Tamamen Katılıyorum</td><td>Katılıyorum</td><td>Kararsızım</td><td>Katılmıyorum</td><td>Tamamen Katılmıyorum</td></tr>
<tr><td rowspan="5">Problem Durumun Yapısı</td><td>5. problem durumu yüzeysel olarak sunulmuştur.</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>6. problemde hedeflenen yüzeysel olarak sunulmuştur.</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>7. çözümü oluşturmak için problem durumu ve/veya hedeflenen durumun yorumlanması gerekmektedir.</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>8. problemin çözümü için uygulanabilecek işlem ve süreçlerin sayısı tam olarak belli değildir.</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>9. problemin çözümü için uygulanabilecek kesin bir dönüştürme işlevi</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
</table>

	(Formül, işlem, kural vs) yoktur.					
Görev Durumun Yapısı	10. problem durumu gerçekçi bir bağlam içerisinde sunulmuştur.	□	□	□	□	□
	11. problemin çözümü için bağlamın kullanılmasına ihtiyaç vardır.	□	□	□	□	□
	12. problemin çözümü için hangi verilerin kullanılacağı ve bunların nasıl organize edileceği konuları net değildir.	□	□	□	□	□
	13. problemin çözülebilmesi için birden fazla alan bilgisine ihtiyaç vardır.	□	□	□	□	□
	14. problemin tek bir çözümü bulunmamaktadır. Problemi çözebilmek için çeşitli çözüm yolları kullanılabilir.	□	□	□	□	□
	15. problemin çözümünü değerlendirebilmek için birden çok ölçütün incelenmesine ihtiyaç vardır.	□	□	□	□	□

16. Problem senaryosunda yapılmasını istediğiniz düzeltme/değişiklik varsa paylaşır mısınız?

G. Science Achievement Test Evaluation Form

Sayın yetkili aşağıdaki form ile size sunulan fen bilgisi alan testini değerlendirmeniz istenmektedir. Öncelikle sorunun belirtke tablosu üzerindeki konu ve kazanımla uyumunu değerlendirmeniz istenmekte daha sonrasında ise test sorusu için nihai kararınız istenmektedir. Eğer bu madde belirtilen kazanımı ölçmeye aday bir madde ise lütfen "gereklidir" seçeneğini, eğer madde konu kapsamında fakat düzenlenmesi veya değiştirilmesi gereken bir madde ise lütfen "yararlı ancak yetersiz" seçeneğini, madde belirtilen özelliği temsil etmiyorsa lütfen "gereksiz" seçeneğini işaretleyiniz.

Teşekkür ederim.
Araştırma Görevlisi Mustafa Güleç

Soru 1	Soru 2
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 3	Soru 4
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 5	Soru 6

□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 7	Soru 8
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 9	Soru 10
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz

Soru 11	Soru 12
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 13	Soru 14
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 15	Soru 16
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 17	Soru 18
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur.	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur.

□ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 19	Soru 20
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 21	Soru 22
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 23	Soru 24

□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz
Soru 25	Soru 26
□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz	□ Soru cümlesi ve cevap seçenekleri belirtke tablosunda verilen konu için uygundur. □ Soru cümlesi ve cevap seçenekleri ile belirtke tablosunda verilen kazanım ile örtüşmektedir. Bu test maddesi; ○ Gereklidir ○ Yararlı ancak yetersiz ○ Gereksiz

H. Interview Questions for Pilot of Science Achievement Test

Fen Bilimleri Testi Ön-Pilot Çalışması Görüşme Soruları

1. Bu soruda anlamını bilmediğin bir sözcük var mı?

2. Soruda sorulmak istenen nedir?

3. Verdiğin cevabı gerekçesi ile kısaca açıklar mısın?

4. Diğer seçenekleri neden seçmediğini söyler misin?

5. Bu soru yeterince anlaşılır mı?

   Hayırsa, sence nasıl anlaşılır bir hale getirilebilir?

İ. Interview Questions for Pilot of Unplugged Algorithm Quiz

Bağlantısız Algoritma Ön-Pilot Çalışması Görüşme Soruları

1. Bu soruda anlamını bilmediğin bir sözcük var mı?
2. Soruda sorulmak istenen nedir?
3. Verdiğin cevabı gerekçesi ile kısaca açıklar mısın?
4. Diğer seçenekleri neden seçmediğini söyler misin?
5. Bu soru yeterince anlaşılır mı?

   Hayırsa, sence nasıl anlaşılır bir hale getirilebilir?

J. Rubric of Unplugged Algorithm Quiz

Bağlantısız Algoritma Sınavı Değerlendirme Rubriği

İSİM	
NUMARA	
TOPLAM PUAN	

Soru 1: 15 puan

A) Dokuz adımda algoritma doğru şekilde oluşturulmuştur. Oluşturulan adımlar aşağıdaki yapılardan biri ile örtüşmektedir.

		Yapı-1			**Yapı-2**	
4.Adım: (1,25x2 puan)	○	9. kareye ilerle ve güneye dön	○	○	9. kareye ilerle ve güneye dön	○
5.Adım: (1,25x2 puan)	○	19. kareye ilerle ve doğuya dön	○	○	19. kareye ilerle ve batıya dön	○
6. Adım: (1,25x2 puan)	○	20. kareye ilerle ve güneye dön	○	○	17. kareye ilerle ve güneye dön	○
7. Adım: (1,25x2 puan)	○	30. kareye ilerle ve batıya dön	○	○	27. kareye ilerle ve doğuya dön	○
8. Adım: (2,5 puan)	○	28. kareye ilerle *dönüş var veya yok*		○	28. kareye ilerle *dönüş var veya yok*	
9. Adım: (2,5 puan)	○	Bitir		○	Bitir	

B) Adım sayısı dikkate alınmadan algoritma doğru sonuca ulaşacak şekilde oluşturulmuştur (8 puan).

2. Soru: 10 puan

Adım	2	2	2
Adım	6	6	5
Adım	1	1	1
Adım	3	3	3
Adım	4	5	6
Adım	5	4	4

Sonuç yandaki sıralamaların biriyle tamamen örtüşmektedir. (10 Puan)	**Sonuç yandaki sıralamaların biriyle kısmen örtüşmektedir. (5 Puan)**	**Sonuç yandaki sıralamaların herhangi biriyle örtüşmemektedir. (0 Puan)**

3. Soru:15 puan

Hata 1: 5. Adım doğuya dön **bulunmuş (2,5 Puan)**	**Hata 2: 7. Adım** on dördüncü kare **bulunmuş (2,5 Puan)**	**Hata 3: 7. Adım** doğuya dön **bulunmuş (2,5 Puan)**
Düzeltme: Batıya dön **olarak düzeltilmiş (2,5 Puan)**	**Düzeltme:** yirminci kare **olarak düzeltilmiş (2,5 Puan)**	**Düzeltme:** batıya dön **olarak düzeltilmiş (2,5 Puan)**

4. Soru:10 puan

1. ifade (2 puan)	4
2. ifade (4 puan)	3
3. ifade (4 puan)	2

5. Soru: 20 puan

ÖLÇÜT	2	1	0,5	0
1. Kullanılan Şekillerin Uygunluğu	Akış şemasının **tamamı** uygun şekiller kullanılarak oluşturulmuştur.	Akış şeması oluşturan şekillerin **bir tanesi** olması gerekenden farklıdır.	Akış şeması oluşturan şekillerin **çoğunluğu** olması gerekenden farklıdır.	Akış şeması oluşturan şekillerin **tamamı** olması gerekenden farklıdır.
2. Akış Yönünün Uygunluğu	Akış şemasının **tamamı** uygun bir yönde (yukarıdan aşağıya veya soldan sağa) oluşturulmuştur.	Akış şemasını **büyük çoğunluğu** uygun bir yönde (yukarıdan aşağıya veya soldan sağa) oluşturulmuştur.	Akış şemasının **büyük çoğunluğu** uygun yönde (yukarıdan aşağıya veya soldan sağa) oluşturulmamıştır.	Akış şemasının yönü anlaşılamamaktadır.
3. Kullanılan Şekillerin Boyutlandırılması	Akış şemasında kullanılan şekillerin **tamamı** uygun bir şekilde boyutlandırılmıştır (Tüm şekillerin boyutları tutarlıdır)	Akış şemasında kullanılan şekillerin **bir tanesi** uygun bir şekilde boyutlandırılmamıştır.	Akış şemasında kullanılan şekillerin **çoğunluğu** uygun bir şekilde boyutlandırılmamıştır.	Akış şemasında kullanılan şekillerin **tamamı** uygun bir şekilde boyutlandırılmamıştır (Tüm şekillerin boyutları tutarsızdır)
4. Kullanılan Şekillerin İsimlendirilmesi (İşlevlerinin Yazılması)	Akış şemasında kullanılan şekillerin **tamamı** uygun bir şekilde isimlendirilmiştir.	Akış şemasında kullanılan şekillerin **bir tanesi** uygun bir şekilde isimlendirilmemiştir.	Akış şemasında kullanılan şekillerin **çoğunluğu** uygun bir şekilde isimlendirilmemiştir.	Akış şemasında kullanılan şekillerin **tamamı** uygun bir şekilde isimlendirilmemiştir.
5. Yönlendirme araçlarının kullanımı	Akış şemasında kullanılan şekillerin **tamamı** uygun yönlendirme araçlarıyla birbirine bağlanmıştır.	Akış şemasında kullanılan şekillerin **bir tanesi** yönlendirme araçlarıyla birbirine bağlanmamıştır.	Akış şemasında kullanılan şekillerin **bir çoğu** yönlendirme araçlarıyla birbirine bağlanmamıştır.	Akış şemasında yönlendirme araçları kullanılmamıştır.
6. Yönlendirme araçlarının yönleri	Akış şemasında kullanılan yönlendirme araçlarının **tamamı** doğru (ok işareti ile) yönlendirilmiştir.	Akış şemasında kullanılan yönlendirme araçlarının **bir tanesi** doğru (ok işareti ile) yönlendirilmemiştir.	Akış şemasında kullanılan yönlendirme araçlarının **bir çoğu** doğru (ok işareti ile) yönlendirilmemiştir.	Akış şemasında kullanılan yönlendirme araçlarının yönleri belirlenememektedir.
7. Kullanılan araçların gerekliliği	Akış şemasında kullanılan **tüm** semboller oluşturulan program için gereklidir.	Akış şemasında kullanılan sembollerden **bir tanesi** oluşturulan program için gerekli değildir.	Akış şemasında kullanılan sembollerden **bir çoğu** oluşturulan program için gerekli değildir.	Akış şemasında kullanılan sembollerin **tümü** oluşturulan program için gereksizdir.
8. Kullanılan yönlendirme araçlarının gerekliliği	Akış şemasında kullanılan **tüm** yönlendirme araçları oluşturulan program için gereklidir.	Akış şemasında kullanılan yönlendirme araçlarından **bir tanesi** oluşturulan program için gerekli değildir.	Akış şemasında kullanılan yönlendirme araçlarından **bir çoğu** oluşturulan program için gerekli değildir.	Akış şemasında kullanılan sembollerin **tümü** oluşturulan program için gereksizdir.
9. Akış Şemasının Mantıksal Akışı	Akış şemasının yapısı mantıksal olarak doğru sıralamadadır.	Akış şemasının yapısında mantıksal olarak **bir adet** sıralama hatası bulunmaktadır.	Akış şemasının yapısında mantıksal olarak **bir çok** sıralama hatası bulunmaktadır.	Akış şemasının yapısı **tamamıyla** mantıksal olarak hatalıdır.
10. Akış Şemasının Genel Yapısı	Akış şeması soruda verilen öğeler kullanılarak derlenmiştir.	Akış şeması soruda verilen öğelerin dışında **bir öğe** kullanılarak veya bir öğe eksik olarak derlenmiştir.	Akış şemasında kullanılan öğelerin **çoğunluğu** soruda verilen öğelerden farklıdır.	Akış şemasında kullanılan öğelerin **tamamı** soruda verilen öğelerden farklıdır.

6. Soru: 15 puan

1.Şekil: (2 puan)	**Yataktan Kalk**
2. Şekil: (1 puan)	**Ellerini ve Yüzünü Yıka** veya **Kıyafetlerini Giy** veya **Kahvaltını Yap** seçeneklerinden bir tanesi
3. Şekil: (1 puan)	**Ellerini ve Yüzünü Yıka** veya **Kıyafetlerini Giy** veya **Kahvaltını Yap** seçeneklerinden 2. şekil için kullanılanın dışındakilerden bir tanesi
4. Şekil: (1 puan)	**Ellerini ve Yüzünü Yıka** veya **Kıyafetlerini Giy** veya **Kahvaltını Yap** seçeneklerinden 2. ve 3. şekil için kullanılmayan
5. Şekil: (2 puan)	**Hava Yağmurlu mu?**
6. Şekil (Hayır Tarafı) (2 puan)	**Şemsiyeni Evde Bırak**
7. Şekil(Evet Tarafı) (2 puan)	**Şemsiyeni Yanına Al**
8. Şekil (2 puan)	**Evden Çık**
9. Şekil (2 puan)	**Bitir**

7. Soru 15 puan

<table>
<tr><td>Ölçüt 1 (Yönlendirme araçlarının kullanımı)</td><td>Akış şemasındaki döngü yapısı uygun bir şekilde oluşturulmuştur ve tüm diğer akış şeması elemanları uygun yönlendirme araçlarıyla birbirine bağlanmıştır (12 p)</td><td>Akış şemasında döngü yapısı eksik ya da hatalı bir şekilde oluşturulmuştur ve tüm diğer akış şeması elemanları yönlendirme araçlarıyla birbirine bağlanmıştır (7 p)</td><td>Akış şemasında döngü yapısı için yönlendirme kullanılmamıştır fakat tüm akış şeması elemanları uygun yönlendirme araçlarıyla birbirine bağlanmıştır (4 p)</td><td>Akış şemasında döngü yapısı için yönlendirme kullanılmamıştır ve şekiller arasındaki yönlendirme araçları eksik kullanılmıştır (2 p)</td><td>Akış şemasında yönlendirme araçları kullanılmamıştır. (0 p)</td></tr>
<tr><td>Ölçüt 2 (Yönlendirme araçlarının yönleri)</td><td>Akış şemasında kullanılan yönlendirme araçlarının tamamı doğru yönlendirilmiştir (2 puan)</td><td>Akış şemasında kullanılan yönlendirme araçlarının çoğunluğu doğru yönlendirilmiştir(1 p)</td><td>Akış şemasında kullanılan yönlendirme araçlarının çoğunluğu doğru yönlendirilmemiştir (0,5 p)</td><td>Akış şemasında kullanılan yönlendirme araçlarının yönleri belirlenememektedir (0 p)</td><td rowspan="2">Ölçüt1 + Ölçüt2 + Ölçüt 3 =</td></tr>
<tr><td>Ölçüt 2 (Dallanma)</td><td colspan="2">Dallanmadaki mantık yapısı (Evet&Hayır) uygun şekilde oluşturulmuştur (1p)</td><td colspan="2">Dallanmadaki mantık yapısı (Evet&Hayır) uygun şekilde oluşturulmamıştır (0 p)</td></tr>
</table>

K. Activity Sheet

Çevreci Robot Etkinlik Yaprağı

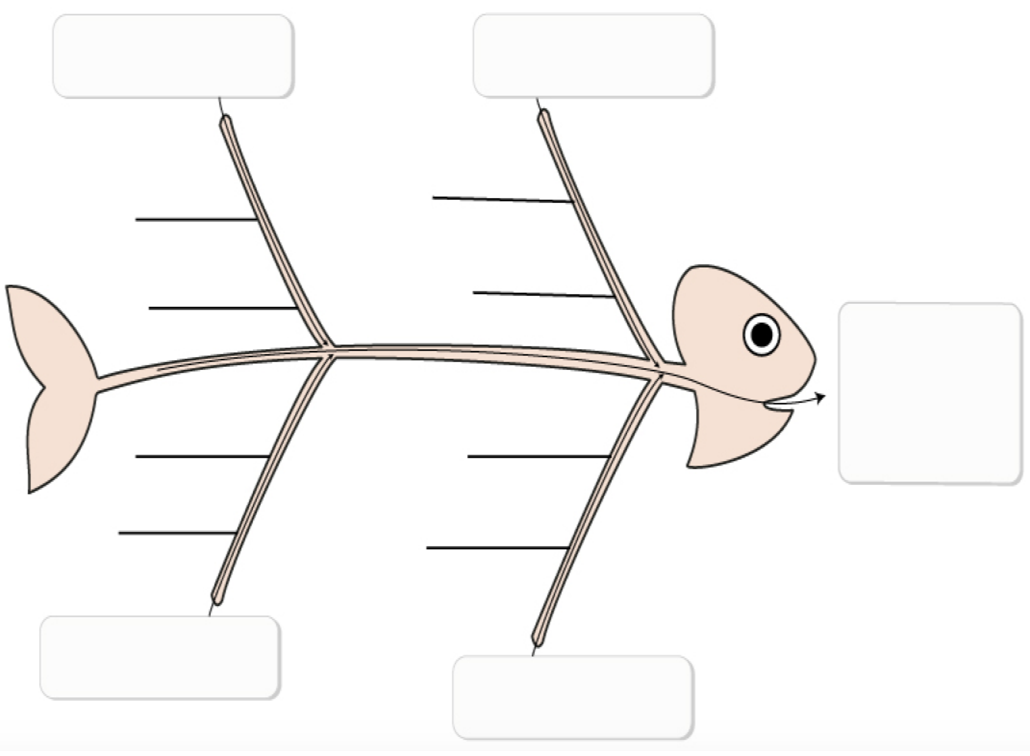
Grup Adı:	
Grup Üyelerinin Ad ve Soyadları:	

Her gün önünden geçtiğimiz çöp kovaları nem açısından zengin ortamlardır. Bu nedenle, içerisine bir yiyecek atıldığı anda çöp kovaları mikroplar için ideal bir üreme ortamı haline dönüşüverir. Sonuç olarak, insanlar başta olmak üzere bu ortamlara maruz kalan tüm canlıları çeşitli sağlık sorunu beklemektedir. Ayrıca bu ortamlar, yaydıkları kötü koku nedeniyle bulundukları çevrenin yaşam kalitesini de oldukça etkilemektedir. Acaba robotlarımız bu konuda neler yapabilir? Çöp kovalarıyla ilgili bu sorunda insanlara yardımcı olabilecek bir robot tasarlamaya ne dersiniz?

1) **Yukarıdaki problemden ne anlıyorsunuz?** Problemde anlatılanları kendi sözcüklerinizle yan taraftaki boşluğa yazınız. Unutmayın bu soruda ve diğer sorularda yazacağınız cümle sayısı önemli değil. Olabildiğince açık ve anlaşılır bir şekilde yazmaya çalışmalısınız.	

2) **Yukarıdaki problemde istenen nedir?** Problemde sizden istenenleri yan taraftaki boşluğa yazınız.	

3) **Yukarıdaki problemin ortaya çıkma nedenleri nelerdir?** Bu probleme neden olabilecek nedenleri aşağıdaki balık kılçığına yerleştiriniz.



4) **Yukarıdaki problem için çözüm önerileriniz nelerdir?** Elinizdeki robot parçaları ve yardımcı malzemeleri dikkate alarak çözüm önerilerinizi yan taraftaki boşluğa sırasıyla yazınız. Birden fazla çözüm önerisi bulmaya çalışmalısınız.	
5) **Yukarıdaki çözüm önerilerinizden hangisini bu problemi çözmek için kullnacaksınız?** Bu önerinizi ayrıntılı bir şekilde	

yan taraftaki boşluğa yazınız.	
6) **Bu problemi çözebilmek için nelere ihtiyacınız olacak (Bilgi, malzeme, robotik parçalar….)?** Çözüm için ihtiyacınız olacak şeyleri yan taraftaki boşluğa yazınız.	

7) **Problemi çözerken robotunuzda hangi eyleyicileri (Eylemi gerçekleştirecek parçalar) kullanmanız gerekecek?** Kullanacağınız eğleyicileri aşağıda işaretleyiniz.

☐ LED ☐ Siren ☐ Motor ☐ Hoparlör

8) **Problemi çözerken robotunuzda kullanmayı planlamadığınız algılayıcılar hangileridir?** Aşağıdaki algılayıcılardan kullanmayı düşünmediklerinizin üzerlerini çiziniz.

- Işık Algılayıcı
- Optik Algılayıcı
- Sıcaklık Algılayıcı
- Mesafe Algılayıcı
- Engel Algılayıcı
- Ses Algılayıcı
- Dokunma Algılayıcı
- Hareket Algılayıcı

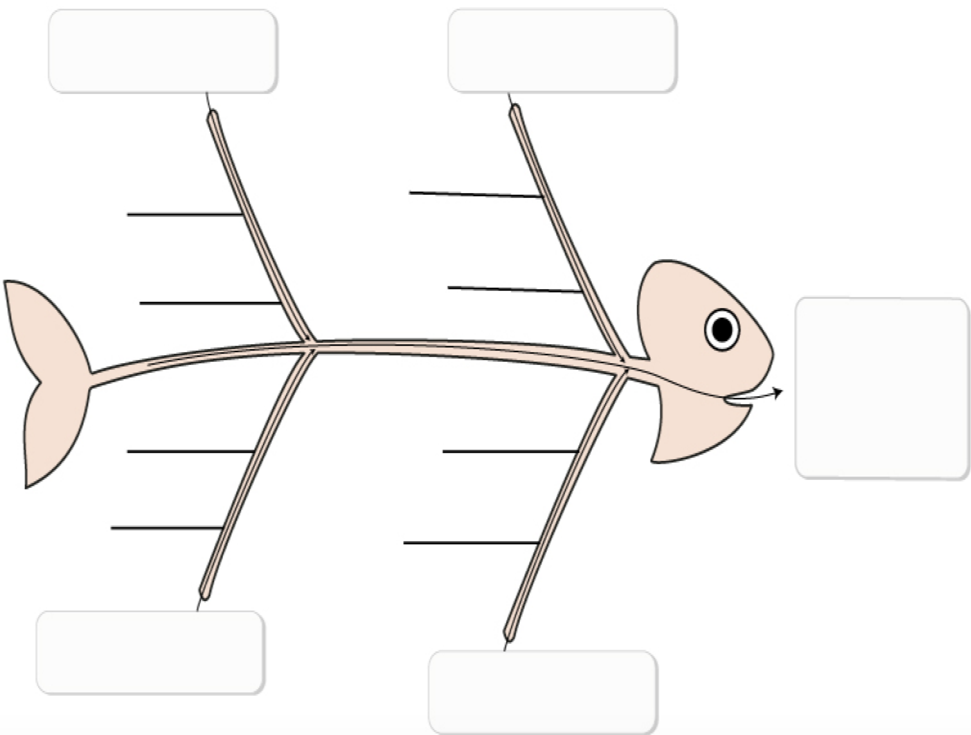
9) **Problemi çözmek için robotunuzda nasıl bir algoritma kullanmanız gerekir?** Robotunuza yükleyeceğiniz algoritmanızı, kullanacağınız robot	

parçalarını düşünerek yan taraftaki boşluğa çiziniz.	

10) **Sizce çözümünüzde neler olacak? Robotunuz neler yapacak?** Beklediğiniz sonuçları yan taraftaki boşluğa yazınız.	
Şimdi bilgisayarınızda robotunuz için algoritmanızı oluşturma zamanı! Öğretmeninize etkinlik kağıdını kontrol ettirin ve bir sonraki ders saatinde yanınızda bulundurmayı unutmayın.	

Environmental Robot Activity Sheet (English Version)

Group Name:	
Names of Group Members:	
The garbage bins that we pass through almost everyday are moisture-rich environments. When food is thrown away, garbage bins turn into an ideal breeding ground for microbes. As a result, living creatures, especially people exposed to these environments, may have several health issues. Also, these environments, due to the bad odor they emit, significantly affect their close circles. What can our robots do for this? How about designing a robot that helps people with the problem of garbage bins?	
1) **What do you understand from the problem above?** Write down what you understand from the problem in space with your own words, please. Do not forget that the number of sentences you write is not important as well as other questions. You're supposed to write as clearly as.	

<table>
<tr><td>2) What is requested in the above problem? Write down what is requested in the space, please.</td><td></td></tr>
<tr><td colspan="2">What are the reasons for this problem? Write the reasons that may cause this problem in the fishbone below, please.

3)</td></tr>
</table>

4) **What are your suggestions for solving the problem above?** Write your suggestions by taking into account the stationery materials and parts of the robot in your hands. You should try to find multiple solutions.	
5) **Which solution proposal will you use to solve this problem?** Write down it in detail.	

6) What will you need to solve this problem (knowledge, material, robotic parts…)? Write the things you will need for the solution	

7) **Which actuators (parts that will act) will you need to use on your robot in your solution?** Please mark the actuators you will use below.

□ LED □ Buzzer □ Dc-Motor □ Speaker

8) **What are the sensors that you do not plan to use on your robot while solving the problem?** Cross out the following sensors that you do not intend to use.

• Light sensor • Optical sensor • Temperature sensor • Proximity sensors • Sound sensor • Touch sensor • Motion sensor	
9) **What algorithm should you use on your robot to solve the problem?** Think about the robot parts you will use and draw your algorithm.	

10) **What do you think will happen in your solution? What will your robot do?** Write your expected results in the space on the side.	

Now it is time to create your algorithm for your robot on your computer! Have your teacher check the activity sheet and do not forget to have it with you in the next lesson.	

L. Form of Reflective Diaries and Drawings

ETKİNLİK DEĞERLENDİRME FORMU

Sevgili arkadaşım,

Bu formda Bilişim Teknolojileri ve Yazılım Dersi kapsamında gerçekleştirdiğimiz Robot Fabrikası adlı etkinlik hakkında sorular bulunmaktadır. Bu sorulara vereceğin cevaplar "Bilişim Teknolojileri ve Bilim Uygulamaları Derslerinin Robotik Problem Çözme Etkinlikleri ile Birleştirilmesi" konulu tez çalışmasında kullanılacaktır. Bu soruları dikkatlice okuyup vereceğin cevapların için şimdiden teşekkür ederim.

Adın ve Soyadın:			
Okul Numaran:		**Grubunuzun Adı:**	

Araştırma Görevlisi

Mustafa GÜLEÇ

Bilişim Teknolojileri ve Yazılım Dersinde gerçekleştirmiş olduğumuz "Robot Fabrikası" adlı etkinliği hayal edip aşağıdaki alana bu etkinliğin resmini çizer misin?

Bu resimde ne çizdin bize anlatır mısın?

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Çizdiğin resimde sen ne yapıyorsun? Anlatır mısın?

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Çizdiğin resimde arkadaşın ne yapıyor? Anlatır mısın?

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Çizdiğin resimde öğretmenin ne yapıyor? Anlatır mısın?

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Çizdiğin resimde robotun ne yapıyor? Anlatır mısın?

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………

Bilişim Teknolojileri ve Yazılım Dersindeki "Robot Fabrikası" adlı etkinlikte bir probleme robotlarımızı kullanarak çözüm bulmaya çalıştık.

- **Bu etkinlikte hoşuna gidenler/gitmeyenler nelerdi?**
- **Etkinlik sırasında zorlandığın zamanlar oldu mu? Neler seni zorladı?**
- **Etkinlik sırasında eğer zorlandığın durumlar olduysa buralarda neler yaptın?**
- **Etkinlikte arkadaşlarınla birlikte nasıl çalıştın? Sence onlarla birlikte çalışmanın iyi/kötü yönleri nelerdi?**
- **Bu etkinlik faydalı mıydı? Eğer faydalı ise hangi açılardan faydalıydı? Sana faydası ne oldu?**
- **Bu etkinlikte öğrendiklerini ileride kullanır mısın? Nasıl? Nerede?**

Şimdi bu etkinlik hakkındaki düşüncelerini yukarıdaki soruları dikkate alarak yazar mısın? Yukarıda cevaplamadığın soru kalmamalı ve düşüncelerini aşağıdaki yazı alanına sığdırmalısın. Teşekkür ederim.

M. Comparison of Robotic Available Robot Kits

	O-Bot	M-Bot	Arduino	Lego
Programlama Dili	I-Dea	Scrach	Scrach	Labview (LV4E)
Çalışılan OS	Windows	Windows & MAC	Windows & MAC	Windows & MAC
Türkçe Dil Desteği	Var	Var	Var	Yok
Arayuz Sadeliği	Oldukça	Sade	Sade	Oldukça
Parça Sayısı	Az	Az	Çok	Çok
Parça Eklenebilmesi	Var- Lego Parçalarıyla Uyumlu	Var –Ardunio Ve Lego Parçalarıyla Uyumlu	Var	Yok-Diğer Sistemlerle Uyumsuz
Kaynaklar/Türkçe	Var/Var	Var/Yok	Var/Var	Var/Var
Fiyat	155$ +Kdv	79$+Kdv	52$+Kdv	350$+KDV
Parça Birleştirme Zorluğu	Kolay/Tornavida Yok	Orta/Tornavida Var	Çok Zor	Zor
Yapılabilecek Uygulama Sayısı	Orta	Orta	Sınırsız	Çok
Parçaların Hareket Esnekliği	Sınırlı	Sınırlı	Sınırsız	Sınırsız
Programın Bilgisayrdan Bağımsız Çalışması	Var	Var	Yok	Var
Bağlantı Tipi	Kablo	Kablo /Blutooth	Kablo	Kablo /Blutooth
Güç Kaynağı	Pil 6 Adt	Batarya+Pil	Adaptor/Usb	Batarya+Pil
Set Kutusunun Taşınabilirliği	Var	Var	Var	Yok
Diğer Aygıtla Kontrol	Yok	Var:Ios-Android	Yok	Var:Ios-Android
Extra Önbilgi	Yok	Yok	Var-Temel Elektronik Bilgisi	Yok
Temin Edilebilirlik	Orta-Tek Firma	Iyi-Internet	Iyi-Internet	Iyi-Internet
Teknik Servis Desteği	Iyi	Orta	Iyi	Iyi
Öğrenci Düzeyine Uygunluk	Iyi	Iyi	Çok Kötü	Kötü
Uygulamaların Günlük Hayata Yakınlığı	Iyi	Iyi	Kötü	Iyi
IR Haberleşme	Yok	Var	Yok	Yok
Robot Haraket Esnekliği	Orta	Orta	-	Iyi

N. Activity Prescriptions

ETKİNLİK YÖNERGESİ

Bilişim Teknolojileri ve Yazılım Dersi robot etkenliklerine hoş geldin. Dönem sonuna kadar bundan sonraki derslerimiz tamamen etkinliklerimizle geçecek. Bir etkinliğimiz 6 ders saati kadar sürecektir. Bu ders saatleri ve içeriklerine göz atmaya ne dersin?

1.Hafta			2. Hafta		
1. Saat (Salı)	**2. Saat (Salı)**	**3. Saat (Perşembe)**	**4. Saat (Salı)**	**5. Saat (Salı)**	**6. Saat (Perşembe)**
Etkinliğe Hazırlık Yapalım ve Video İzleyelim	Etkinlik Yaprağını Dolduralım	İdea'da Robotumuzu Programlayalım	Ürünümüzü Oluşturalım		Diğer Arkadaşlarımıza Sunalım

Peki Etkinliklerimiz Nasıl Olacak?

- Etkinliklerde gruplar halinde çalışacağız (3 kişi).
- Her grup yeşil, beyaz ve sarı renk kartlı üyelerden oluşacak.
- Peki, grubumuzun ismi ne olacak? Grup kurallarımız ne olacak? Düşünmeye başlayabiliriz :)

Etkinlik Grupları:

- Grup içerisinde çok çalışmamız gerektiği için görev dağılımı yapmalıyız:

Etkinlik Kağıdı Sorumlusu: Her grupta etkinlik kağıdına verilen ortak kararları yazacak, etkinlik kağıdını eve götürüp diğer derslere de getirecek olan kişi.

Malzeme Sorumlusu: Seçilecek olan malzemeler için kuraya katılacak olan ve grup arkadaşlarının fikirlerini alarak bu malzemlerin kullanımından sorumlu olacak kişi.

Bilgisayar Sorumlusu: Etkinlik kağıdına grubun ortak kararı ile çizilen algoritmayı diğer grup arkadaşlarının yardımı ve katkısı ile bilgisayara aktaracak olan kişi.

- Unutmayalım grup üyeleri tüm işleri birlikte yapar fakat bazı üyeler o görevde diğer grup arkadaşlarına göre daha fazla sorumluluğa sahip olabilir.
- Ayrıca grup üyeleri örneğin hastalık durumunda okula gelmeyebilir. Bu tip durumlarda diğer grup üyeleri onun görevini aksatmadan grubun işleyişini devam ettirmelidir.

Etkinlik Sırasında Yanımızda Neler Bulunmalı?

Algılayıcı Kağıdı:

- Robot parçalarını kolayca hatırlamak için etkinlikler sırasında algılayıcıların tanıtımın yapıldığı özet kağıtlarını yanımızda bulundurmalıyız.

Etkinlik Kağıdı:

- Etkinlik kağıdı bize etkinlik sırasında yardımcı olması için hazırlanmıştır. Bu nedenle üzerindeki tüm alanları eksiksiz doldurursak daha kolay ilerleyebiliriz.
- Etkinlik kağıtları dağıtılınca öncelikle grup adını ve grup üyelerinin isimlerini yazmamız gerekir.
- Etkinlik kağıdı her derste yanımızda bulunmalı ve dersin başlangıcında gözden geçirilip yapılan işler ve yapılacak olanlar grup içerisinde görüşülmelidir.

Etkinlik Kuralları:

1. Grup çalışması sırasında sessiz olmalıyız. Grup içinde ve diğer gruplarla konuşurken sesimizi diğer sınıf arkadaşlarımızı rahatsız etmeyecek düzeyde tutmalıyız.
2. Diğer gruplarla etkileşim içerisinde olabiliriz. Birbirimize yardımcı olmamız güzel bir şey ancak diğer grupları rahatsız edici söylemlerden kaçınmalıyız.
3. Gruplar farklı hızlarda çalışabilir. Diğer grupların bizden ileride ya da geride olması hiçbir zaman önemli olmamalı çünkü önemli olan hızımız değil grubumuzun güzel şekilde çalışabilmesidir.
4. Yardımcı malzemeler etkinliklerin sonunda ürünü ortaya koyacağımız zaman kura ile dağıtılacaktır. Burada öncelik sırası her hafta kura ile belirlenecektir. Yardımcı malzemelerin sayısı tüm gruplara göre ayarlandığı için her grup buradaki ürünlerden eşit sayıda almalıdır.
5. Etkinlik kağıtlarını doldurduğumuz derslerde gruplara verilecek yardımcı malzemelerin bir örneği tahtanın önünde duracaktır. Bu malzemeler sadece görüp ona göre çözümler üretmemiz için orada olacaklarından bu malzemeleri almamamız gerekmektedir.
6. Ürünlerin oluşturulduğu saatlerde teneffüse çıkılması zorunludur. Ürünlerimizin bozulmaması için sınıf kapısı kapatılacak ve ders saatinde tekrar açılacaktır. Ayrıca robot parçalarını ve yardımcı malzemeleri sınıf dışına çıkarmamalıyız.
7. Oluşturduğumuz ürünlerin üzerine grup isimlerini yazmalıyız yoksa kaybolabilir.
8. Bilgisayara kaydettiğimiz İdea program dosyalarının isimlerini *grupismi_etkinlikadı* şeklinde kaydetmeliyiz.
9. Gruplarımızla yapacağınız bu çalışmalar Bilişim Teknolojileri ve Yazılım Dersi kapsamında değerlendirilecek ve bu ders kapsamında notlandırılacaktır.
10. Etkinlik sonrası bize verilecek olan formları evde doldurmamız çok önemlidir. Diğer etkinliğin başladığı gün bu formları okula getirip öğretmenimize teslim etmeliyiz.

O. Peer Evaluation Form

AKRAN DEĞERLENDİRME FORMU

Adın ve Soyadın:			
Okul Numaran:		**Grubunuzun Adı:**	

Sevgili arkadaşım,

Aşağıdaki tablo Bilişim Teknolojileri ve Yazılım Dersi kapsamında bu hafta gerçekleştirdiğimiz .... adlı etkinlik sürecinde diğer grup arkadaşlarını değerlendirmen amacıyla hazırlanmıştır. Tablodaki noktalı (....) alanlara adını yazacağın grup arkadaşın hakkındaki düşüncelerini en iyi yansıtan seçeneğin yanına çarpı (X) işareti koyarak tabloyu doldurur musun? **Bu kısımda vereceğin cevaplar kesinlikle gizli tutulacaktır.**

Grubundaki İlk Arkadaşının Adı ve Soyadı:..

Bu boşluklara yukarıda adını ve soyadını yazdığın grup arkadaşının sadece adını yazman yeterli ↓	**Her Zaman**	**Çoğu Zaman**	**Bazen**	**Neredeyse Hiçbir Zaman**
.... etkinlik sırasında grubumuzun planına uygun hareket etti.				
.... etkinlik sırasında kendi üzerine düşen görevleri yerine getirdi.				
.... etkinlik sırasında kendi görevlerini zamanında tamamladı.				
.... etkinlik sırasında diğer grup üyelerine yardımcı oldu.				
.... etkinlik sırasında diğer grup üyelerinin görüşlerine önem verdi.				

Grubundaki İkinci Arkadaşının Adı ve Soyadı:..

Bu boşluklara yukarıda adını ve soyadını yazdığın grup arkadaşının sadece adını yazman yeterli ↓	**Her Zaman**	**Çoğu Zaman**	**Bazen**	**Neredeyse Hiçbir Zaman**
.... etkinlik sırasında grubumuzun planına uygun hareket etti.				
.... etkinlik sırasında kendi üzerine düşen görevleri yerine getirdi.				
.... etkinlik sırasında kendi görevlerini zamanında tamamladı.				
.... etkinlik sırasında diğer grup üyelerine yardımcı oldu.				
.... etkinlik sırasında diğer grup üyelerinin görüşlerine önem verdi.				

Formu doldurduktan sonra lütfen kağıdı katlayıp sana verilen zarfa koy ve zarfı öğretmenine ver.

1

P. Participation Certificate

T.C. MİLLÎ EĞİTİM BAKANLIĞI

CAHİT ZARİFOĞLU
İMAM HATİP ORTAOKULU

robotsan®

Katılım Belgesi

Öğrencimiz ....'a 2018-2019 Öğretim Yılı Bilişim Teknolojileri Dersi kapsamında gerçekleştirilen Eğitsel Robotlu Problem Çözme Etkinliğine katılımından dolayı teşekkür eder, başarılarının devamını dileriz.

Mustafa GÜLEÇ
Araştırma Görevlisi

[redacted]
BT Öğretmeni

Q. List of Stationery Materials

Makas
Yapıştırıcı
Fon kartonu
El feneri
Sticker
Çift taraflı bant
Elektrik bandı
Mukavva
Slikon
Yapışkanlı kağıt
Mandal
Şeffaf dosya
Fon kartonu
Oluklu karton
Tahta kalemi
Kuru boya
Rafya
Halı kaydırmaz
Para bandı
Koli bandı
Keçeli kalem
Fon kartonu
Keçe
Postit
Simli karton
Silinebilir boya
Vantuz

R. Science Achievement Test

AD SOYAD:		SINIF:	
ÖĞRENCİ NUMARASI:		SÜRE:	25 Dakika

FEN BİLİMLERİ TESTİ

SORU 1: Aşağıdakilerden hangisi sürtünme kuvvetini arttırmaya yönelik yapılan uygulamalara bir örnektir?

A) Kapı menteşelerinin yağlanması

B) Buzdolabının altına tekerlek takılması

C) Gemilerin ön kısmının "V" şeklinde olması

D) Araçlara kışa uygun lastiklerin takılması

SORU 2:

Çiftçi Ahmet Bey'in yaptığı açıklamanın nedeni aşağıdakilerden hangisidir?

A) Traktörün ön tekerleğinin arka tekerleğinden daha küçük boyutta olması.

B) Traktörün normal araçlardan farklı yakıt tüketmesi.

C) Traktörün hareket ettiği yüzeylerde sürtünme kuvvetinin farklı olması.

D) Toprak alanın asfalt ve çim alanlara göre daha geniş yüzeye sahip olması.

SORU 3: Sürtünme kuvveti günlük hayatta karşımıza hem olumlu hem de olumsuz etkileriyle çıkmaktadır.

Buna göre;

I. Hareket halindeki arabanın frenine basınca durması

II. Çalışan makine parçalarının bir süre sonra aşınması

III. Kara kalem ile kağıt üzerine yazı yazılabilmesi

ifadelerinin hangileri sürtünme kuvvetinin olumlu etkilerindendir?

A) I ve II

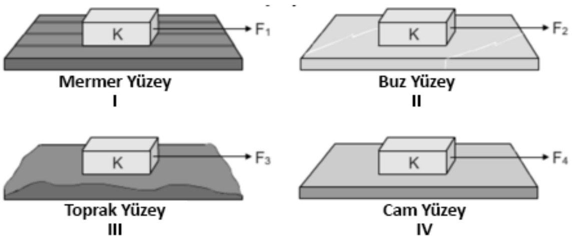
B) I ve III

C) II ve III

D) I, II ve III

SORU 4:

Bir öğrenci bir cismin farklı yüzeyler üzerinde farklı zorlukta hareket ettirilebileceğini göstermek için aşağıdaki deney düzeneğini hazırlıyor. Bu dört düzenekte K cismini aynı hızda hareket ettirebilmek için öğrenci sırasıyla F_1, F_2, F_3 ve F_4 kuvvetlerini uygulamıştır.



Buna göre öğrencinin uyguladığı yukarıdaki kuvvetlerden hangisi <u>en büyüktür?</u>

A) F_1 B) F_2 C) F_3 D) F_4

SORU 7:

Mum

Ateş

Ampul

Masa Lambası

Yukarıda verilen ışık kaynaklarının hangilerinde ışığın yayılması doğru olarak gösterilmiştir?

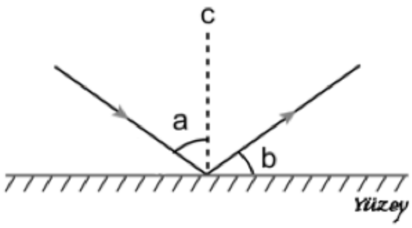
A) Mum ve Ateş

B) Mum ve Masa Lambası

C) Ateş ve Ampul

D) Ampul ve Masa Lambası

<u>SORU 8:</u> Aşağıda düzgün bir yüzeye gönderilen ışına ait yansıma olayının çizimi verilmiştir.



c doğrusu yüzeye dik bir doğru olduğuna göre,

I. a açısı gelme açısıdır.

II. b açısı yansıma açısıdır.

III. c doğrusu yüzeyin normalidir.

ifadelerinden hangileri doğrudur?

A) I ve II

B) II ve III

C) I ve III

D) I, II ve III

<u>Soru 9:</u>

Şekilde bir örneği verilen güneş panelleri güneş enerjisini elektrik enerjisine dönüştüren sistemlerdir. Bu araçların yaygınlaşması ile enerji sorununa önemli ölçüde çözüm bulunması beklenmektedir.

Buna göre aşağıdakilerden hangisi bu araçların sağlayacağı faydalardan biri <u>olamaz?</u>

A) Güneş ışınları ile kendi kendine büyüyen bitkiler

B) Güneş ışınları ile kendi elektriğini üreten evler

C) Güneş enerjisiyle hareket eden elektrikli araçlar

D) Güneş enerjisiyle yanıp sönen trafik lambaları

<u>Soru 10:</u> Aydınlanmanın günlük yaşamımızdaki etkileri olumlu ve olumsuz olarak iki grupta incelenebilir.

Buna göre;

Cem: Karanlık ortamların güvenliğinin sağlanması

Cansu: Trafik ışıkları yardımıyla trafik akışının sağlanması

Ceylan: Güneş panelleri ile elektrik üretilmesi

ifadelerini söyleyen öğrencilerden hangileri aydınlanmanın günlük yaşamımıza olumlu etkilerine örnek vermiştir?

A) Cem ve Cansu

B) Cansu ve Ceylan

C) Cem ve Ceylan

D) Cem, Cansu ve Ceylan

<u>SORU 11:</u> Işığı geçirme özelliklerine göre aşağıdaki maddeleri sınıflandırdığımızda hangisi diğerlerinden <u>farklıdır?</u>

A) Ayna

B) Güneş gözlüğü

C) Buzlu cam

D) Yağlı kağıt

<u>SORU 12:</u> Her bir bölmesi farklı maddelerden yapılmış pencereden dışarıyı seyreden Can aşağıdaki şekildeki gibi bir görüntü elde ediyor. Bu görüntüye göre Can, K bölmesinden bulanık bir şekilde dışarıdaki manzarayı görebildiğini, L bölmesinden hiç görüntü alamadığını ve M bölmesinden en net şekilde manzarayı görebildiğini söylüyor.

Buna göre,

I. K bölmesindeki cisim opak bir maddedir.

II. L bölmesindeki cisim bir metal levha olabilir.

III. M bölmesindeki cisim saydam bir maddedir.

ifadelerinden hangileri doğrudur?

A) I ve II

B) II ve III

C) I ve III

D) I, II ve III

<u>SORU 13:</u> Işığı geçiren maddelere …1… madde denir. Bu maddelere örnek olarak …2… verilebilir. Işığı geçirmeyen maddelere ise …3… denir ve …4… bu maddelere bir örnektir.

Yukarıdaki cümlelerde boş bırakılan yerlere aşağıdakilerden hangileri getirilebilir?

	1	2	3	4
A)	Opak	Karton	Saydam	Buzlu Cam
B)	Saydam	Buzlu Cam	Yarı Saydam	Mermer
C)	Saydam	Cam	Opak	Mermer
D)	Yarı Saydam	Buzlu Cam	Opak	Cam

<u>SORU 14:</u> Çevre kirliliği ile ilgili aşağıdaki verilenlerden hangisi <u>yanlıştır?</u>

A) Hava kirliliğinde insan faaliyetlerinin bir etkisi yoktur

B) Su kirliliği toprağa atılan yabancı maddelerin suya karışması sonucu ortaya çıkar

C) Plansız kentleşme, nüfus artışı ve sanayileşme çevre kirliliğini arttırır

D) Işık kirliliği ışık kaynaklarının yanlış yerde ve yanlış sayıda kullanılması sonucu oluşmaktadır

<u>SORU 15:</u> Aşağıdaki verilen seçeneklerden hangisi <u>doğrudan</u> hava kirliliğini önlemeye yönelik bir uygulamadır?

A) Geri dönüşüm olabilen maddelerin hammadde olarak kullanılması

B) Tarımda doğal gübrenin kullanılması

C) Ulaşımda kişisel araçlar yerine toplu taşıma araçlarının tercih edilmesi

D) Verimli toprak alanların kentleşmeye kapatılması

<u>SORU 16:</u>

I. Fabrikaların baca sistemlerinde filtre kullanılmaması

II. Tarım alanlarında yapay gübre ve ilaçların fazla kullanılması

III. Plansız kentleşme ile şehirlerde nüfusun artması

Yukarıdaki verilenlerden hangileri çevre kirliliğine neden olmaktadır?

A) I ve II

B) II ve III

C) I ve III

D) I, II ve III

SORU 17:

I. Fosil yakıt kullanımını azaltmaları için insanları bilgilendirici poster hazırlamak

II. Evsel atıkların geri dönüşüme kazandırılması için proje başlatmak

III. Tarım ilaçlarının yanlış kullanımının önüne geçmek için çiftçileri bilgilendirici bir film yayınlamak

Yukarıdaki ifadelerden hangisi çevre kirliliğini önlemeye yönelik alınabilecek tedbirler arasındadır?

A) I ve II

B) II ve III

C) I ve III

D) I, II ve III

SORU 18: Fen bilimleri dersinde "Yıkıcı Doğa Olayları" konusu için bir grup öğrenci aşağıdaki bilgi fişlerini hazırlamıştır.

Ali — Deprem bölgesinde çok katlı binalar yapılmamalıdır.

Ayşe — Ülkemizde deprem olayının görülmesi mümkün değildir.

Atakan — Depremin ne zaman gerçekleşeceğini bilemeyiz.

Aysel — Deprem çantasında ilk yardım malzemeleri bulundurulmalıdır.

Buna göre öğrencilerden hangisinin fişinde verilen bilgi yanlıştır?

A) Ali

B) Ayşe

C) Atakan

D) Aysel

<u>SORU 19:</u> "Depremler engellenemez ancak alınacak küçük önlemlerle zararları azaltılabilir" düşüncesiyle üç kişi evlerinde yaptıkları davranışları söylemiştir.

Ayşe: Mutfaktaki cam kavanoz ve şişeleri kilitli ya da kapalı bir dolaba koydum.

Ali: Atlamak için en yakın balkon ya da pencerenin yerini öğrendim.

Ahmet: Tavanda bulunan aydınlatma araçlarının bağlantılarını sağlamlaştırdım.

Bu bilgilere göre bu kişilerden hangileri deprem öncesinde yapılması gereken hazırlıklardan birini yapmıştır?

A) Ayşe ve Ali

B) Ayşe ve Ahmet

C) Ali ve Ahmet

D) Ali, Ayşe ve Ahmet

<u>SORU 20:</u> Bir bölgede gerçekleşen depremin meydana gelme nedeni aşağıdaki seçeneklerin hangisinde doğru verilmiştir?

A) Ay'ın oluşturduğu gel-git hareketi

B) Toprağın yerçekimi ve eğim etkisiyle aşağı doğru hareket etmesi

C) Yer kabuğunu oluşturan levhaların hareket etmesi

D) Hızlı esen rüzgarların kendi kuvvetinin yanında çevresini de etkilemesi

<u>SORU 21:</u> Aşağıdaki verilenlerden hangisi deprem sırasında yapılması gereken bir davranıştır?

I. Sağlam bir eşyanın yanına kapanıp, başımızı korumak.	**II.** Evin güvenli yerlerini tespit edip korunma planı yapmak.
III. Düşebilecek eşyaları duvara sabitlemek.	**IV.** Evdeki sigorta ve vanaların yerlerini öğrenmek.

A) I B) II C) III D) IV

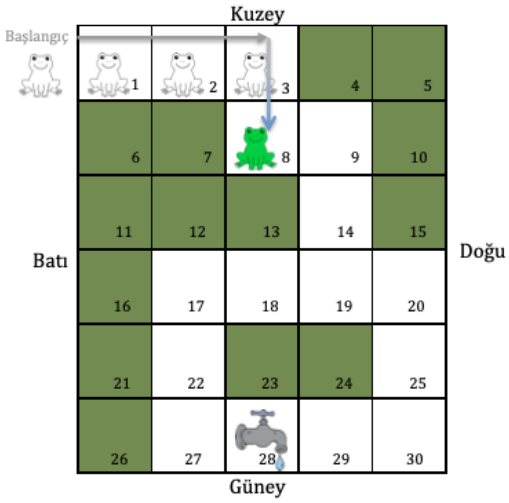
Test soruları MEB Ölçme, Değerlendirme ve Sınav Hizmetleri Genel Müdürlüğü (ÖDSGM) ve Eğitim Bilişim Ağı (EBA) tarafından sağlanan içeriklerden uyarlanmıştır.

S. Unplugged Algorithm Quiz

Ad-Soyad	
Sınıf	
Numara	
Süre	**25 dk**

Bağlantısız
Algoritma Soruları

1. Çok fazla susayan kurbağa su bulabilmek için büyük çalılıkların arasından geçebileceği doğru yolu bulması gerekmektedir. Sence kurbağa doğru yolu bulabilmek için hangi algoritmayı kullanmalıdır? Kurbağanın musluğa ulaşmak için kullanması gereken adımları aşağıdaki adım listesine yazmaya ne dersin? İlk dört adım senin için yazıldı bile.

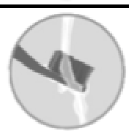


1. Adım: Başla
2. Adım: Üçüncü kareye ilerle ve güneye dön
3. Adım: Sekizinci kareye ilerle ve doğuya dön
4. Adım: ....
5. Adım:..

6. Adım:..
7. Adım:..
8. Adım:..
9. Adım:..

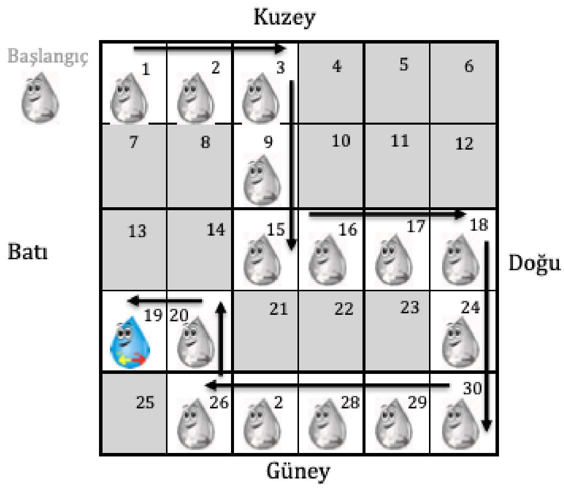
1

2. Aşağıda diş fırçalamak için gerekli altı adım karışık olarak verilmiştir. Diş fırçalama algoritmasını oluşturmak için bu adımların sıra numaralarını verebilir misin? İlk adım senin için yapıldı.

	Diş macununu diş fırçasına dikkatlice sürelim.	Adım:........
	Diş fırçamızı ve diş macunumuzu kutusuna koyalım.	Adım:........
	Diş fırçamızı bir elimizle tutalım.	Adım:....1....
	Diş fırçamızı dişlerimize sürerek onları fırçalayalım.	Adım:........
	Ağzımızı hiç diş macunu kalmayacak şekilde suyla çalkalayalım.	Adım:........
	Diş fırçamızı suyla güzelce üzerinde hiç macun kalmayacak şekilde temizleyelim.	Adım:........

3. Aşağıda suya çok ihtiyacı olan bir çiçeğe su taşımak isteyen yağmur tanesinin kullanmış olduğu yol oklarla çizilerek Şekil-1'de verilmiştir. Bu yolu bulmak için yağmur tanesinin kullandığı algoritmayı tahmin eden bir kişi ise Şekil-2'deki algoritmayı oluşturmuştur. Fakat hazırlamış olduğu algoritmayı kontrol ederken, bazı adımlarının hatalı olduğunu fark etmiştir. Sence bu kişi algoritmasında hangi adımları yanlış vermiştir? Hatalı olan adımları hemen alttaki boşluğa düzelterek yazar mısın? Yapılan ilk hatalı adım senin için bulundu ve düzeltildi.

Şekil-1



Şekil-2

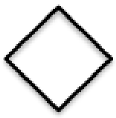
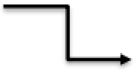
1.Adım: Başla
2.Adım: Üçüncü kareye ilerle ve güneye dön
3.Adım: On beşinci kareye ilerle ve doğuya dön
4. Adım: On altıncı kareye ilerle ve güneye dön
5. Adım: Otuzuncu kareye ilerle ve doğuya dön
6. Adım: Yirmi altıncı kareye ilerle ve kuzeye dön
7. Adım: On dördüncü kareye ilerle ve doğuya dön
8. Adım: On dokuzuncu kareye ilerle
9. Adım: Bitir

Algoritmadaki Hatalı Adım ve Yapılması Gereken Düzeltmeler

4. Adım: "On altıncı kareye ilerle ve güneye dön" yerine "On sekizinci kareye ilerle ve güneye dön olmalı"

3

4. Aşağıdaki isimleri ve şekilleri verilen akış şeması elemanları karışmış. Bu elemanların isim ve şekillerini işlevleriyle eşleştirebilir misin? Elips elemanı senin için eşleştirildi bile.

1 Elips		Algoritmadaki sembolleri birbirlerine bağlamak ve akış yönünü göstermek için kullanılır.	_
2 Dikdörtgen		Bu sembol bir duruma karar verme merkezidir. Birkaç farklı seçenek varsa bu sembol kullanılarak seçenekler yazılır.	_
3 Eşkenar Dörtgen		Algoritmaların akışında yapılacak olan eylemi / işlemi belirtmek için kullanılır.	_
4 Ok		Akışı başlatan ve bitiren şekildir. Algoritmamızın başlangıcında ve bitişinde bu sembolü kullanırız.	1

5. Aşağıda adımları verilen ayran yapma algoritmanın akış şemasını yanındaki boş alana çizmeye ne dersin? İlk adım senin için yapıldı.

Adım 1:Başla

Adım 2: Yoğurdu kaba koy.

Adım 3: Su ekle.

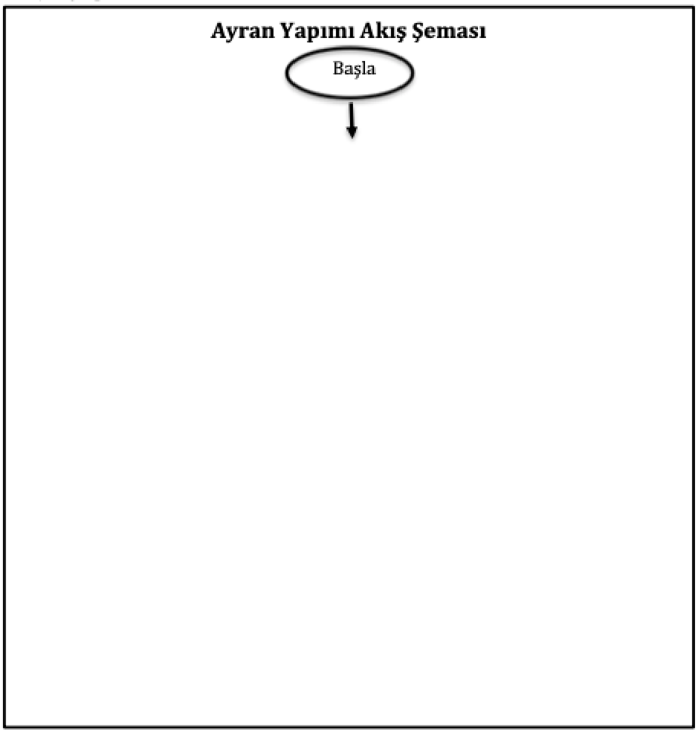
Adım 4: Çırp.

Adım 5: Tuz koy.

Adım 6: Tekrar çırp.

Adım 7: Bardağa doldur.

Adım 8: Bitir.



4

6. Aşağıda sabah rutini algoritmasının adımları karışık olarak verilmiştir. Bu adımların verilen akış şeması içerisine yerleştirilmesi gerekmektedir. Bunu yapmaya ne dersin? İlk adım senin için yazıldı bile.

~~Başla~~

Ellerini ve Yüzünü Yıka

Şemsiyeni Yanına Al

Yataktan Kalk

Kahvaltını Yap

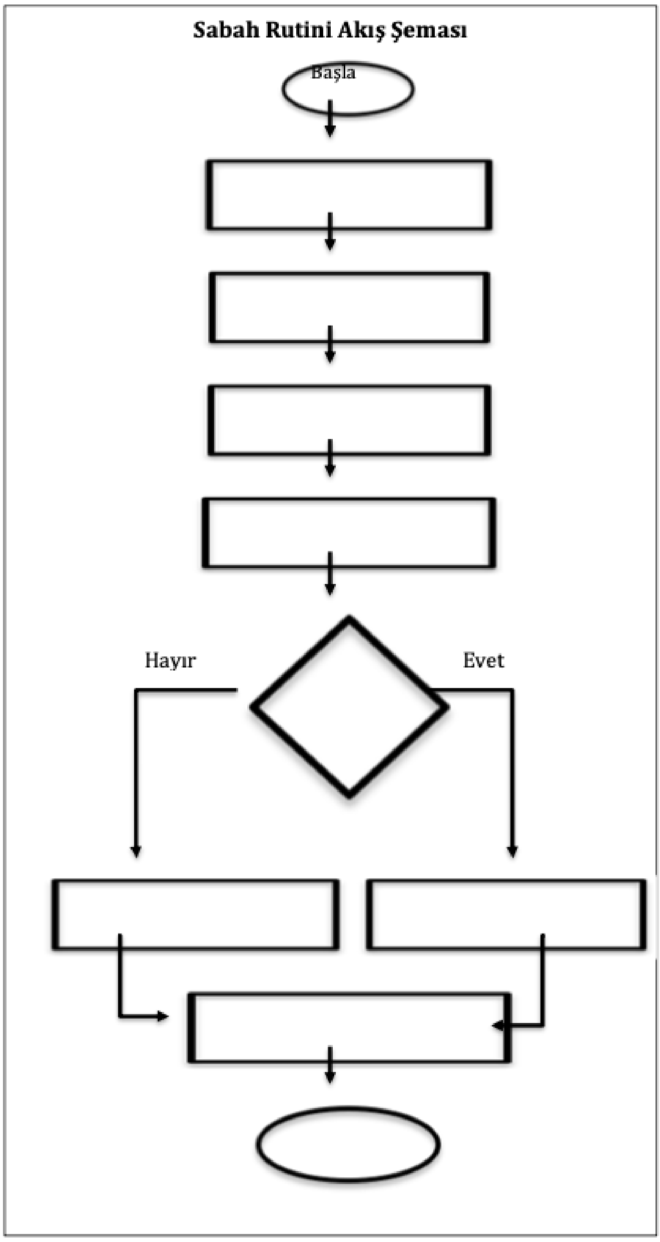
Hava Yağmurlu mu?

Kıyafetlerini Giy

Şemsiyeni Evde Bırak

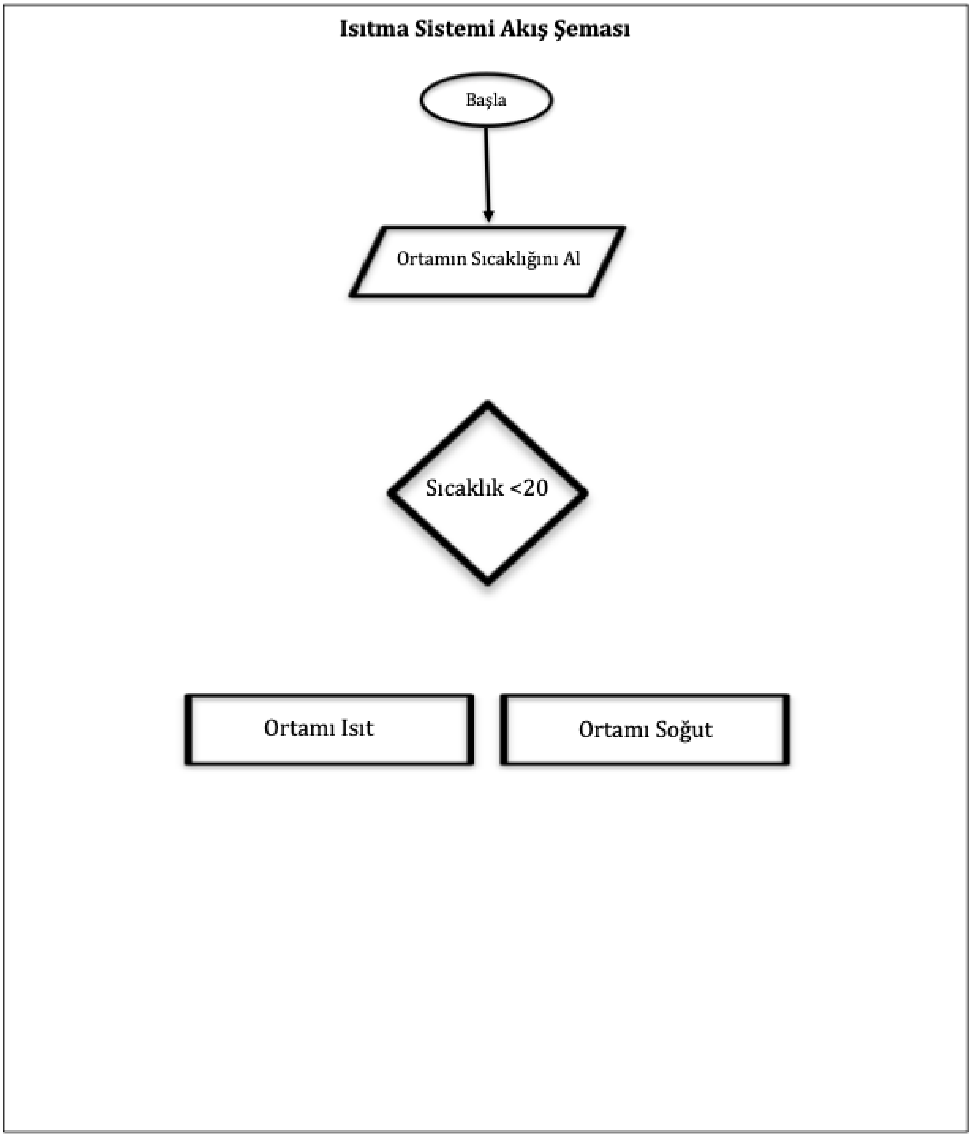
Bitir

Evden Çık



5

7. Kışın soğuktan yazın ise sıcaktan sebzeleri zarar gören bir çiftçi, serasının sürekli hava sıcaklığını kontrol edip ortamdaki hava sıcaklığını 20 santigrat derece civarlarında tutmak istemektedir. Bu sistem için sıcaklık 20 santigrat derecenin altına düştüğünde ortamı ısıtan, 20 santigrat derecenin üstünde ise ortamı soğutan bir akış şeması kullanan çiftçimiz akış şeması elemanlarını çizmiş fakat tamamlayamamıştır. Sadece yönlendirme elemanlarının eksik olduğu aşağıdaki akış şemasına okları kullanarak istediği özellikte bir sistem oluşturması için çiftçimize yardımcı olur musun? İlk yönlendirme elemanı senin için çizildi bile.



T. Activity Sceniorios

Robot Fabrikası
Türkiye'nin ilk insansı robot fabrikası 2017 yılının Kasım ayında Konya'da seri üretime geçti. Fabrika "Akınsoft" isimli yazılım firmasına ait 2 bin 700 metrekaresi kapalı toplam 11 bin metrekare alandan oluşan oldukça büyük bir tesis olma özelliğine sahip. İlerleyen dönemde robot bilim insanı olarak bu fabrikada çalıştığınızı hayal edin. Müşterileriniz robotların kaygan zeminlerde hareket ederken zorlandıklarından şikayet etmekte ve firma olarak bu soruna çözüm bulmanızı istemekteler. Bu durumda robotların farklı zeminlerde rahatlıkla hareket etmeleri için neler yaparsınız? Robotlarınızı bu sorun karşısında yeniden tasarlamaya ne dersiniz?
Robot Factory (English Version)
Turkey's first humanoid robot factory in Konya began mass production in November 2017. The factory, which consists of a total of 11 thousand square meters, of which 2 thousand 700 square meters are closed, belonging to the company named "Akınsoft", has the characteristic of being a very large facility. Imagine that in the future, you are working as robot scientist in this factory. Your customers are complaining that they have difficulty in moving robots on slippery floors and they want you to find a solution to this problem as a company. In this situation, what would you do to make robots move comfortably on different kinds of floors? How about designing your robots again to solve this problem?
Güneşin Zararlı Etkilerinden Koruyan Robot
Pırıl pırıl güneşli günlerde dışarıda vakit geçirmek gibisi yoktur. İyi hissettirmesinin yanında, güneş ışınları özellikle kemik gelişimi için ihtiyacımız olan "D vitamini" için en önemli doğal kaynağımızdır. Bu olumlu özelliğinin aksine güneş ışınlarına gereğinden fazla maruz kaldığımızda başta güneş yanıkları olmak üzere istenmeyen bir çok sonuçla karşılaşabiliriz. Ayrıca bu durum bazı cilt hastalıklarına da neden olmaktadır. Bu durumdan insanları korumak için acaba robotlarımız ne yapabilir? İnsanları güneş ışınlarının zararlı etkilerinden korumaya yardımcı olabilecek bir robot tasarlamaya ne dersiniz?
Robot Protecting From The Harmful Effect Of The Sun (Lifeguard Robot) (English Version)
There is nothing like spending time outside on bright sunny days. Besides feeling good, the sun rays are our most important natural source for the "vitamin D" we need especially for bone development. Contrary to its positive effects, when we are exposed to sunlight more than necessary, we encounter many undesirable consequences like sunburn. Additionally, this situation may cause some skin diseases. What can our robots do to protect people from this situation? How about designing a robot that can help people for the harmful effects of the rays of the sun?
Yardımsever Robot
Tüm dünyada olduğu gibi ülkemizde de deprem, sel, heyelan ve kasırga gibi yıkıcı doğa olayları (doğal afetler) oldukça sık görülmektedir. Doğal afetler bir kez başladığında durdurulması mümkün olmayan ve sonuçlarıyla insanlara çeşitli zararlar verebilen olaylardır. Ne yazık ki yıkıcı doğa olaylarından en fazla zarar gören insanların başında engelli bireyler gelmektedir. Doğal afetlerin oluşumunu engelleyemeyiz fakat

alabileceğimiz tedbirlerle yıkıcı doğa olaylarının engelli bireylere verebilecekleri zararları en aza indirebiliriz. Sizce bu tedbirleri almamızda robotlar bize nasıl yardımcı olabilir? Yıkıcı doğa olaylarına karşı engelli bireylere yardımcı olabilecek bir robot tasarlamaya ne dersiniz?
Helpful Robot (Savior Robot) (English Version) Destructive natural events such as earthquakes, floods, landslides, and hurricanes are often seen in our country and around the world. Natural disasters are events that cannot be halted when they begin. They also cause various harm to people with their consequences. Unfortunately, individuals with disabilities are the most damaged people from devastating natural phenomena. We cannot prevent the occurrence of natural disasters, but with precautions that we take, we can minimize the damage of them on people with disabilties. How can robots help us in taking these precautions? How about designing a robot that can help disabled individuals against destructive natural phenomena?
Güneşin Zararlı Etkilerinden Koruyan Robot Her gün önünden geçtiğimiz çöp kovaları nem açısından zengin ortamlardır. Bu nedenle, içerisine bir yiyecek atıldığı anda çöp kovaları mikroplar için ideal bir üreme ortamı haline dönüşüverir. Sonuç olarak, insanlar başta olmak üzere bu ortamlara maruz kalan tüm canlıları çeşitli sağlık sorunu beklemektedir. Ayrıca bu ortamlar, yaydıkları kötü koku nedeniyle bulundukları çevrenin yaşam kalitesini de oldukça etkilemektedir. Acaba robotlarımız bu konuda neler yapabilir? Çöp kovalarıyla ilgili bu sorunda insanlara yardımcı olabilecek bir robot tasarlamaya ne dersiniz?
Environmental Robot (Scavenger Robot) (English Version) The garbage bins that we pass through almost everyday are moisture-rich environments. When food is thrown away, garbage bins turn into an ideal breeding ground for microbes. As a result, living creatures, especially people exposed to these environments, may have several health issues. Also, these environments, due to the bad odor they emit, significantly affect their close circles. What can our robots do for this? How about designing a robot that helps people with the problem of garbage bins?

U. Guideline in Turkish

Klavuz

Etkinlik Aşaması :

1. HAZIRLIK:

1.1. Hazırlık Kontrolü

- Sınıf düzeyi
- Ön bilgi kontrolü
- Gerekli becerileri arama
- Yanlış anlamaları kaldırma
- Öğretmenin hazırlığı
- Altyapı kontrolü

1.2. Öğrenmeyi Organize Etme

- Öğrenci sayısı
- Ekipman sayısı
- Aktivite yapısını sürdürme
- Yedek öğretmen sağlama
- Grupları oluşturma

2. GİRİŞ:

2.1. Motivasyon Arttırma

- Teknoloji kullanma
- Tanıtım videosu kullanma
- İşbirliğine teşvik etme

2.2. Ekipman Sağlama

- Kaynakları kolayca ulaşılabilir kılma

3.4.5.KAĞIT ÇALIŞMASI- PROGRAMLAMA-ÜRETİM

3.1.Destek

- Etkinlik yaprağı kullanımı
- Öğrencileri yönlendirme
- Akran yönlendirmesine teşvik etme
- Öğretim yardımcıları sağlama (programlamada)

3.2.Yaygın Sorunları Ele Alma

- Gürültüyü önleme
- Grup sorunlarını aşma
- Kırtasiye malzemeleri dağıtma (tasarımda)

6. DEĞERLENDİRME:

6.1.Güvenilirlik

- Hedefleri dikkate alma
- Ölçme aracı kullanma (etkinlik yaprağı, yansıtıcı günlük, akran değerlendirme formu)

6.2.Çözümleri Sunma

- Başarı hissini garanti etme
- Teknik ve tasarıma dayalı açıklamaları kabul etme

7. KAPANIŞ:

7.1.Katılımı Doğrulama

- Sertifika sağlama

V. Research Approval from Applied Ethics Research Center

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05 Mayıs 2017

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof. Dr. Zahide YILDIRIM ;

Danışmanlığını yaptığınız doktora öğrencisi Mustafa GÜLEÇ' in *"Bilişim Teknolojileri ve Bilim Uygulamaları Derslerinin Eğitsel Robotlu Problem Çözme Etkinlikleri ile Birleştirilmesi"* başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2017-EGT-099** protokol numarası ile **18.05.2017 – 30.09.2018** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

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2010 June	Bucak Public Education Center	Master Trainer

FOREIGN LANGUAGES

English

PUBLICATIONS

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