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The Effect of Gamified STEM Practices on Students' Intrinsic Motivation, Critical Thinking Disposition Levels, and Perception of Problem-Solving Skills

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Abstract

The aim of this research is to examine the effect of gamified STEM activities on 3rd and 4th grade students' intrinsic motivation, perception of problem-solving skills, and critical thinking disposition. In this mixed method study, problem solving skills perception scale, critical thinking disposition instrument and intrinsic motivation inventory formed the quantitative data, while, activity worksheets, field notes and student interviews, formed the qualitative data. After 8 weeks of implementation, quantitative data were analyzed and significant differences were found between pre-test and post-test results on students' critical thinking disposition level. Although it is not significant, the results showed that an increase was found in students' perception of problem-solving skills. Besides, students' intrinsic motivation levels were found high, as well as students stated that "gamified STEM" activities help them learn and practice the content and they found the activities enjoyable, competitive, and exciting. Moreover, the rewards and badges that they won at the end of the activities were motivating.

Introduction

The human profile that the current century needs is responsible individuals who can identify and solve the existing problem, develop a critical perspective, are open to innovations, are creative, produce and work collaboratively. The STEM approach, which consists of the initials of the words Science, Technology, Engineering, Mathematics, is an integrated education program based on the fields of science and mathematics and utilizing the opportunities provided by technology and engineering design processes. The changes and innovations that occur in the science education, where science and technology are based, lead to current approaches in the field of education and different theories in education. STEM education, one of the most important developments in twenty-first century education; is an approach that integrates the content and skills of science, mathematics, engineering and technology (Ceylan, 2014). Recent research in the field of science education has shown that the use of an engineering design-based approach to improve science education plays an active role (Kelly, 2010). In addition, it is aimed to internalize external motivation by using gamification method based on motivation (Gökkaya and Gökkkaya, 2014).

The concept of gamification, first voiced by Nick Pelling in 2002, although it has been on the agenda for a long time (Marczewski, 2013); educational games can be associated with concepts such as educational gameplay, fun interaction, and game-based technologies (Karataş, 2014). According to a study that defines the range of benefits associated with gamification, it is stated that it both develops student participation and learning from a technological perspective that is necessary for today's students (Şahin and Namlı, 2016). As a result of STEM studies initiated by the National Science Foundation (NSF) in the United States in 1990, it was proposed to integrate STEM trainings and activities into the curriculum and in 2003, they were placed in the master program at Virginia Tech University (Özsoy, 2017). In the current economic situation and the importance of STEM education in Turkey also increased. For the economic development of a country, engineering and technology fields must be developed. STEM education approach contributes to the development of 21st century skills such as critical thinking, problem solving, collaboration, technology literacy. With STEM education, it is emphasized that students' 21st century skills are developed, and they can easily solve information-based life problems (Tseng, Chang, Lou & Chen, 2013) and they can exhibit collaborative work.

Consequently, it is hypothesized that STEM-related activities integrated with gamification method may provide meaningful and lasting learning by solving the problems encountered during the instruction. In the literature, limited number of studies have been carried out in STEM activities conducted with primary school students is also seen as a need. STEM activities are not carried out efficiently within the curriculum, it is especially true for science and mathematics courses due to the heavy content along with the high school entrance exam. However, the new generation, whom we call as the generation Z, has been developing digital skills from a young age and their needs and expectations are a challenge for teachers, hence adding game elements to the course and STEM related activities is seen as a need (Özkan & Samur, 2017; Vu & Feinsteim, 2017).

Integrated STEM Education

In the 1990s, the National Science Foundation, which used the word SMET for science, mathematics, engineering and technology, was born after a UBV program officer complained that SMET was too similar to the English word smut (Sanders, 2009). When the relevant literature is examined, there are two different approaches to what STEM is. One of these approaches is to provide training in an integrated manner by treating two or more disciplines together (Morrison, 2006). The approach expressed as integrated STEM provides activities and projects by addressing different disciplines and their relationships with each other in order to provide more lasting and effective learning rather than treating these disciplines as strict academic disciplines (Yıldırım, 2018; Yıldırım & Altun, 2014). STEM education aims to provide students with an interdisciplinary perspective on the problems they face (Adıgüzel, Ayar & Şahin, 2014). Çorlu (2013) argues that STEM education is highly important for students because of converting the theoretical knowledge learned in science, mathematics, technology and engineering into applications and products. Today, as the need for thinking, producing, questioning and creative individuals in the fields of science, technology, engineering and mathematics increases, new and different programs such as STEM education must be implemented for the learning and teaching processes in these fields (Yıldırım & Altun, 2015). STEM education establishes a relationship between science, mathematics, technology and engineering disciplines, enabling learning to be carried out with a holistic approach (Smith & Karr-Kidwall, 2000). Another objective in STEM education is to identify components for effective learning environments (Erdoğan, 2014). Rather than giving theoretical knowledge to Science, Technology, Engineering and Mathematics courses, the task of the teachers, therefore, is to guide students and to bring the students to the level where they can make product development, invention and innovation through high level thinking (Ministry of Education, 2016).

Project Based Learning

Project-based learning is a teaching approach that uses student-centered inquiry processes to develop a product with real-life connections and applications (Johnson & Lamb, 2017). Project-based learning has become a tradition in America's public schools, dating back to the works of Francis W. Parker and John Dewey in the 19th century (Burlbaw, Ortwein & Williams, 2013). STEM Project-based learning redesigns a professional teaching power empowered with the skills necessary to design learning experiences that maximize student potential (Capraro & Slough, 2013). The concept of project-based learning is not a new idea, but the emphasis on linking actual STEM education with middle and high school education with secondary practices is new (Capraro & Slough, 2013). National science standards for the science and mathematics curriculum, cornerstones of STEM education, are dynamic and each standard strives to include more research and project-based learning, so that teachers and students will be able to use these methods appropriately (Slough & Milan, 2013).

Pryor and Kang (2013) argue that the project-based learning process should be supported by the concepts of questioning, critical thinking and decision-making in order to encourage the pedagogical implementation of the three aspects of "joint group work," "emphasis on analysis and evaluation", and "reflection". Critical thinking is the investigation to determine the nature of the problem before solving a problem (Dewey, 1997). Project-based learning also consists of inquiry-based tasks (Nastu, 2009). Therefore, project-based learning and inquiry-based learning (Bruner, 1961) show similarities in student-centered teaching (Şahin, 2013) in respect to incorporate “discovery learning”. Although having some contrasting elements, they show similarities with project-based learning by incorporating similar design elements such as research, idea creation, analysis of ideas and reflection (Şahin, 2013). Şenocak (2005) shows the difference between these two concepts in Table 1.

Table 1. The Differences between project-based learning and problem-based learning (Şenocak, 2005)

Project-based learning	Problem-based learning
Starting point is project.	The starting point is the problem.
Product model.	Research model.
A concrete product is produced.	A concrete product may not be produced.
It has a wide range of topics and time coverage.	It has a limited coverage of time and subject.
It is the direct application of information.	It is about the retrieving information.
It is applied with small age group.	It is applied with adult groups.
The problem is mostly in the problem format.	The problem is in the form of a scenario or case study.

Problem Based Learning

In STEM education, which starts with authentic problem of knowledge society (APoKS) and expects students to make a design for solving the problem, the student can achieve gains from different disciplines in the design creation process (Çorlu, 2017). Savin-Baden (2000) defined problem-based learning as a flexible and characterizable approach for learning, meaning that it can be applied in a variety of ways in different contexts, subjects and disciplines so that students are encouraged to restructure knowledge they already know in a realistic context, acquire new knowledge for longer terms (Kilroy, 2004).

Meta-analysis studies demonstrate the positive impact of problem-based learning on success in comparison to traditional teaching in different areas, different subjects and different student groups (Dağyar & Demirel, 2014). Moreover, it is stated that problem-based learning is highly effective in increasing academic success and attitudes in STEM fields. A study conducted with 3852 high school students studying at STEM schools showed that students developed positive attitudes towards STEM related careers (LaForce, Noble & Blackwell, 2017).

STEM and 21st Century Skills

It is emphasized that students can easily solve the authentic problems of knowledge society (Çorlu, 2017) defined as the complex and dynamic problems experienced by the 21st century knowledge society (Chang, Chen, Lou, & Tseng 2013) and they can perform collaborative work thanks to STEM education. Capraro and Slough (2013) argued that STEM education enables students use their 21st century skills at the highest level. The importance of skills such as thinking, producing, questioning and creativity in the fields of STEM increases today, it is necessary to implement programs such as STEM education for gaining these skills (Yıldırım & Altun, 2015). STEM Education Report of Turkey (2015) emphasizes that it is not possible to give children such skills as creativity, critical thinking, collaboration, problem solving skills through traditional approaches, besides, STEM contents are given as isolated parts from each other in the current curriculum. Therefore, MEB (2016) suggests that STEM education is compulsory for gaining students aforementioned skills.

Critical Thinking and Problem Solving Skills

Critical thinking covers concepts such as assumption, concept, bias, inference, and argument (Paul, 1985). Mcpeck (1981) argues that individuals with critical thinking skills can make critical reflections and solve problems by establishing connection with their previous knowledge. Therefore, the acquisition of critical thinking skills creates the basis of the acquisition of many other skills (Akdemir & Yavuz, 2018). Pekbay (2017) states that practicing critical thinking and problem solving skills should start at an early age. Ütay (2017) stated that the practices improving students' problem-solving skills are generally problems that require the process of analysis, synthesis and evaluation; therefore, it is argued that STEM experiences might have possible effects on critical thinking skills (Capraro & Slough, 2008; Duran & Şendağ, 2012). It is also found that the lessons conducted with STEM applications positively affected the problem solving skills of students (Ceylan, 2014; Pekbay, 2017); however, after giving STEM education, Elliot (2001) found no significant difference on university students' problem solving skills. Therefore, in this study, students' perceptions to authentic problems of knowledge society and their ability to solve these problems were collected rather than their ability to solve science and math problems, and the scale developed by Ekici and Balım (2013) was used to measure students' perception of problem solving skills.

Gamification in Education

With the introduction of levels and badges for the activities and objectives of the scouting movement in 1910 (Nistor & Jacob, 2018), gamification has emerged as a popular trend in recent years (Hanus & Fox, 2015). It is the use of game elements in non-game environments to motivate targeted behaviors with behavioral theories (Samur & Şahin, 2017). In addition, the most comprehensive definition of gamification is the use of game elements rather than games to increase user experience and user participation through non-game applications (Deterding, Sicart, Nacke, O'Hara & Dixon, 2011). The aim of the gamification is to help students learn and practice in a fun way, to increase their motivation, participation (Dichev & Dicheva, 2017) and to improve their performance while having fun (Mert & Samur, 2018) and providing more positive feedback (Muntean, 2011) compared to traditional classroom settings. Since increasing motivation is not an easy task, the effective design and implementation of the gaming experience requires great effort (Dominguez vd., 2013). Effective application of gamification in learning is a complex process because gamification does not only mean integrating technology for rewards (Bruke, 2014). Unlike traditional classroom settings, the goal is to create a fun, smooth competitive environment that will increase students' interest and motivation to the highest level (Lee & Hammer, 2011; Özer & Biçen, 2017). Game components, dynamics and mechanics must be correctly integrated into the curriculum in order to successfully carry out the gamification in education (Şahin & Samur, 2017; Yıldırım & Demir, 2016).

Gamified STEM Education

Gamification is a research area attracting and motivating students of all levels in education and also in various disciplines (Clark & Ernst, 2009). However, there is a need to investigate how gamification can be used as a method to teach and practice the STEM related content, and its effects on students. Because, gamified STEM may enhance problem-based learning that focuses on active learning in which students work with different tools and resources to solve their problems (Bourazeri, Heidmann, Coelho & Morini, 2017). For this aim, various institutions in Turkey such as the Turkish Informatics Foundation (TBV) and the Educational Volunteers Foundation of Turkey (TEGV) conducted various projects and competitions based on gamified STEM activities.

Some of the game elements are easily found when existing STEM practices and activities are examined. STEM studies are based on an authentic problems of knowledge society in the first place. In the lesson plans prepared for this study, it is conveyed to the students through a *story* which is also a game element that allows player to learn and experience the content in a well-designed educational game (Fiş Erümit, 2016; Samur & Özkan, 2019). In STEM activities, students are required to apply engineering design steps to solve the problem and fulfill their tasks initially given with a story. Throughout the process, students are subject to the *rules* given, and their designs receive immediate *feedback* during the assessment process. Feedback is one of the essential elements of gamification, which aims to allow students to practice with the possibility of making mistakes (Fiş Erümit, 2016; Samur, 2019), that may improve students' various skills and knowledge about the content (Shute, 2007).

Research Questions

In this study, answers to the following research questions were sought:

1. Is there a significant difference between the students' pre-and-post-test scores of critical thinking dispositions when gamified STEM practices are conducted during the course?
2. Is there a significant difference between the students' pre-and-post-test scores of problem-solving skills perceptions when gamified STEM practices are conducted during the course?
3. What are the students' intrinsic motivation levels when gamified STEM practices are conducted during the course?
4. What are the students' views on the practices in the course designed with the gamified STEM practices?

Method

This study aims to investigate the impact of gamified STEM applications on intrinsic motivation levels, critical thinking skills disposition and perceptions of problem-solving skills of primary school students. For this aim quantitative data supported with qualitative data were collected to analyze the study. Data "triangulation" is used to improve the accuracy of decisions by analyzing different types of data on the same phenomenon (Jick, 1979). Single group pre-test post-test study design was used as an experimental research method (as shown in Table 1). In this design, the difference of pre-and-posttest means is tested to see if it is significant (O_1-O_2) (Büyüköztürk et al., 2016).

Table 1. Single Group Pre-and-post-test Design

Group	Pre-test	Treatment	Post-test
G	O1+O2	*X*	O1+O2+O3+O4

O1: Problem solving skills perception scale

O2: Critical thinking disposition instrument

O3: Intrinsic motivation inventory

O4: Semi-structured interviews

X: Gamified STEM practices

In the qualitative dimension of the study, interview questions were prepared, and interviews were conducted with the aim of determining the quality of the solutions offered by the students to the authentic problems of knowledge society and the effects of gamification on their perceptions. Qualitative data were evaluated through content analysis, defined as a systematic, reproducible system in which the words in the text are summarized in smaller content categories by coding according to certain rules (Büyüköztürk et al., 2016).

Study Group

The study group of the research consists of 26 third and fourth grade students (10 male and 16 female students) who chose Science Club of a private school in Istanbul during the spring term of 2017-2018 academic year. The students' ages range from 10 to 11 with different academic levels. At the beginning of the academic year, 30 different club preferences were offered to the students, therefore it can be deduced that they have high motivation. Since the students select their clubs at the beginning of the semester, no random selection was possible. Students chose Science Club with the expectation of experiencing fun experiments as they like them, therefore they were not aware of the gamified STEM activities.

Procedures

In the second semester of the 2017-2018 academic year, the application was carried out with the students in the last two lecture hours allocated to club classes on Wednesdays in a science lab at a private school for 8 weeks. In the first week, "Critical Thinking Disposition Instrument" and "Problem Solving Skills Perception Scale" were applied as pre-tests without any explanation to the students. While the pre-tests were applied, the questions were reflected on the board and read one by one by the teacher to make sure every student understood the items. After the completion of the pre-tests, the students were informed about the activities and the flow of the activities during the 8-week period. It was stated that the events starting from the following week would be group work and groups would be randomly selected each week. These choices were made by giving the numbers 1 to 5 to the students. Each student continued to work in their own group. The basic flow of the seven different lesson plans started from the second week is based on the understanding through design approach (Çorlu, 2017), which is one of the most important approaches in STEM education. During the activities, students were observed and field notes were taken for qualitative data. At the end of the eighth week, the activities were completed in all classes and "Critical Thinking Disposition Instrument" and "Problem Solving Skills Perception Scale" were applied as post-tests. Moreover, intrinsic motivation inventory was used to analyze the students' intrinsic motivation after the treatment. Finally, one-to-one semi-structured student interviews were made at the end of the study.

Data Collection Tools

Problem-solving Skills Perception Scale. After thorough research, many measurement tools were found examining problem solving skills. However, most of them were aimed at solving social problems rather than solving daily life problems (Koçoğlu, 2017). In addition, the scales were carried out mostly on individuals receiving higher education. In this study, the problem-solving skills perception scale developed by Ekici and Balım (2013) was used as it is suitable for primary school students and focuses on the solution of problems encountered in daily life. The scale has two-factor structure consisting of 22 items in 5-point Likert type and Cronbach alpha reliability coefficient calculated as α=0,88.

Critical Thinking Disposition Instrument. The Turkish form of UF / EMI critical thinking disposition instrument, which was translated into Turkish by Kılıç and Şen (2014), was used in this study. The three-factor instrument has 25-items with 5-likert type classified as "Strongly agree", "Agree", "Indecisive", "Disagree" and "Strongly disagree". The Cronbach alpha reliability coefficient calculated as α=0,91. As this scale was adapted to Turkish for using with secondary school students, the validity and reliability study was re-conducted by Koçoğlu (2017) in order to be used in primary school and Cronbach alpha was found α=0,96.

Intrinsic Motivation Inventory. In order to determine the intrinsic motivation levels of students, a 7-point Likert-type intrinsic movitation inventory firstly developed by Ryan in 1982 (Çalışkur & Demirhan, 2013) with 32 items was used. In the scoring, the new item numbers were valid since the original item sorting and subtraction changes were required after conducting the reliability validity study of the inventory. In the factor analysis of the original of the inventory, 18 items corresponding to Interest / Loving, Perceived Competence, Effort / Importance, Pressure / Tension were identified and a medium level relationship was found by comparing the 18-item and 16-item versions of the inventory distributed to 4 factor groups (Çalışkur & Demirhan, 2013) and Cronbach alpha reliability coefficient calculated as α=0.86.

Observation Notes. In order to support the quantitative data, observation notes were also used to support data sources. The researcher was also the observer, applying the gamified STEM activities to the Science Club students throughout the process. A formal observation procedure was followed during the application. Notes were taken during observations made by the researcher for seven weeks. These notes were kept under two headings as “What happened in the class?”, “What happened after the class?” for each lesson. In addition to the observation notes, audio and video recordings were taken for watching the lessons later to make sure nothing was missed during the lessons. Parental consents from each student were taken before the study.

Interviews. Before the study, a semi-structured interview form was prepared in order to determine the opinions of the students about the gamified STEM activities. While preparing the interview forms, expert opinions were taken under four main themes. These themes were “General views on practice”, “Views on academic success”, “Views on motivation and attitudes towards STEM”. Later, open-ended questions were written under each theme by the researcher to reveal students' views on these themes based on the existing literature. Semi-structured interviews were conducted with four volunteer students.

Course Materials based on STEM Training and Engineering Design Rules

There are multiple engineering design models with various steps (Capraro & Slought, 2013), however any design activity takes place over a period and has a step-by-step methodology (Plan & Khandani, 2005). In many models, teamwork and design are the two main themes of the engineering design process (Tayal, 2013). In the engineering design model used in this study has seven-stages and there is a transformation between these stages until the final design solution is completed (Morgan, Moon & Barroso, 2013). They are (1) define the problem and to solve this problem to meet the needs or to meet the needs of a solution proposal to produce and develop the steps to take to express the engineering design steps; (1) identifying the problem, (2) researching the problem and identifying needs, (3) producing alternative solutions, (4) choosing the best solution, (5) designing (developing & prototyping), (6) testing and editing and (7) presenting the final product (Tayal, 2013). In order to integrate engineering acquisition into this study, engineering design processes is used and it is depicted in Figure 1.

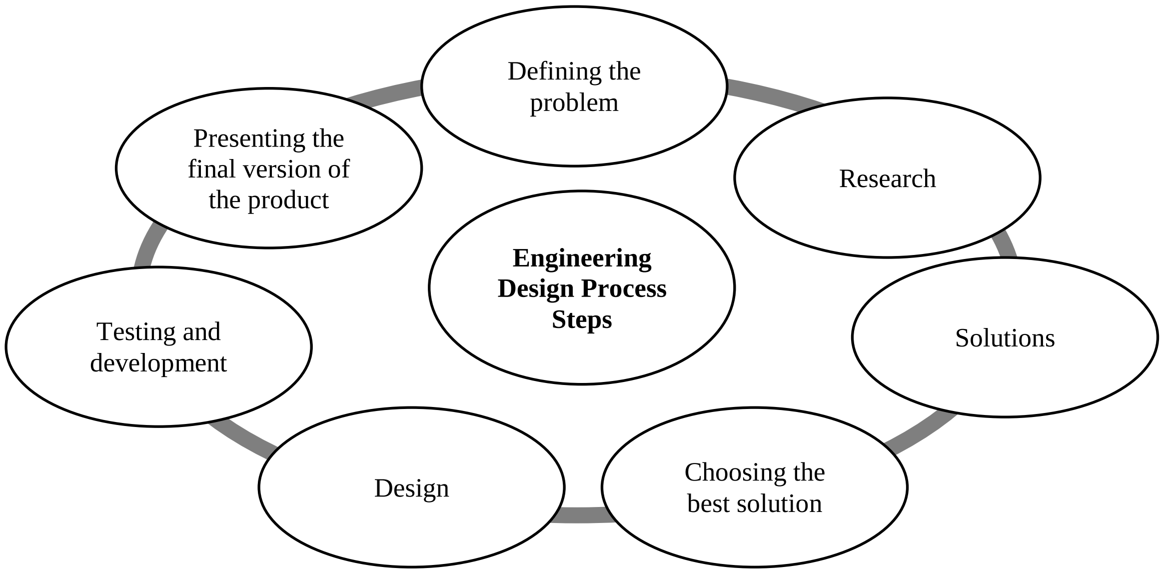
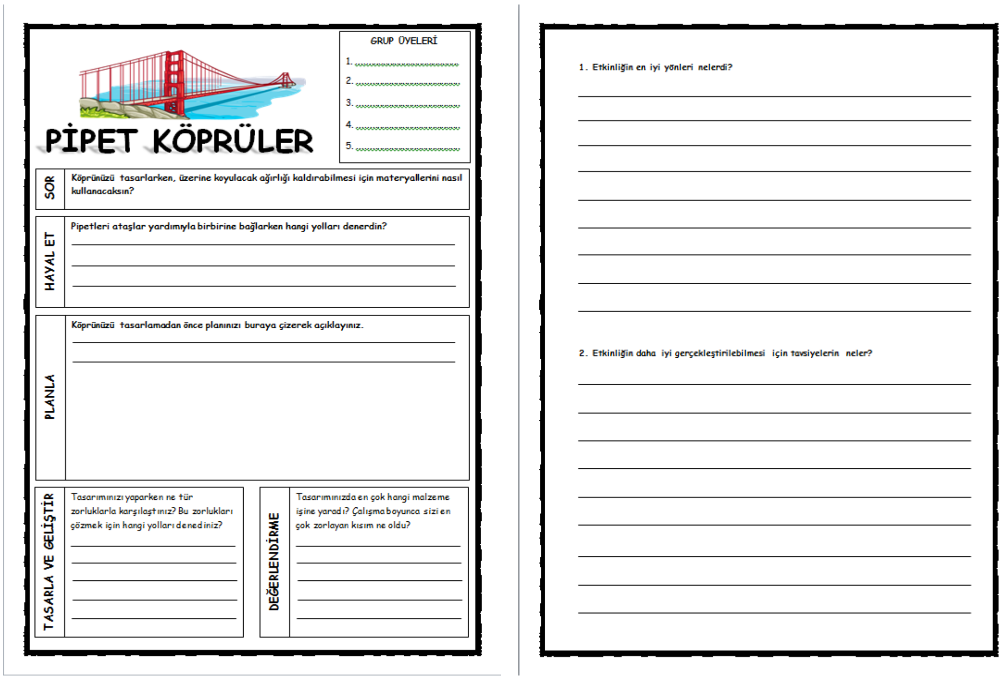


Figure 1. Engineering Design Process Steps (Morgan, Moon & Barroso, 2013)

Lesson Plans. Within the scope of the research, 7 different lesson plans were prepared to fit the curriculum agenda. Some STEM studies in the literature were revised and game elements were integrated to gamify the STEM lesson plans. These lesson plans are based on STEM learning outcomes and they were consulted and approved by the subject matter experts in gamification. Each plan is divided into three sections as introduction, development and final. Presentations were prepared for students to announce the lesson plans during the implementation of the club lessons. These presentations consist of four main topics: "story / information", "task", "material", and "rules". In the introductory part of the task, the students were given information about science learning outcomes and their previous knowledge was recalled. In the next stage, students were given ten minutes to make ideas and design the solution of the problem situation given for that task. The students were given a certain amount of "STEM money" and they were asked to select the materials they wanted from the list given (depicted in Figure 2). After completing the sections stated in the worksheets and deciding how and to what extent the materials will be used, they started the design process. The allocated time for the design varied based on the activity between 20 and 30 minutes. When the time was up for the designs, the students filled out the evaluation sections of the worksheets. After each group presented their products, each product was tested and scored according to the degree of matching with the criteria. The points and badges were distributed to the students at the end of the course and the results were recorded on the leadership table. The scores in the leadership table were calculated and the group with the highest score was determined and the certificate of achievement was given to the group by the teacher.

Game Elements. The game elements used in the gamified STEM lesson plans prepared within the scope of the study are time, reward, score, progress bar, badges, leaderboard, materials, story, competition, characters, penalty, goals and rule.

Worksheets / Study Papers. Student worksheets consisted of five parts. These sections were: Ask, imagine, plan, design and develop, evaluation. This sections in the worksheet were prepared by considering the steps in the engineering design process. In order to obtain student opinions and evaluate the efficiency of the tasks, there were questions such as "What are the best aspects of the task?", "What are your recommendations to make the task better?" on the last page of the worksheet (as depicted in Figure 2).


PİPET KÖPRÜLER
GRUP ÜYELERİ
1.
2.
3.
4.
5.
SOR
Köprünüzü tasarlarken, üzerine koyulacak ağırlığı kaldırabilmesi için materyallerini nasıl kullanacaksın?
HAYAL ET
Pipetleri ataşlar yardımıyla birbirine bağlarken hangi yolları denerdin?
PLANLA
Köprünüzü tasarlamadan önce planınızı buraya çizerek açıklayınız.
TASARLA VE GELİŞTİR
Tasarımınızı yaparken ne tür zorluklarla karşılaştınız? Bu zorlukları çözmek için hangi yolları denediniz?
DEĞERLENDİRME
Tasarımınızda en çok hangi malzeme işine yaradı? Çalışma boyunca sizi en çok zorlayan kısım ne oldu?

1. Etkinliğin en iyi yönleri nelerdi?
2. Etkinliğin daha iyi gerçekleştirilebilmesi için tavsiyelerin neler?

Figure 2. Worksheet Sample

Badges. The students were given a badge at the end of each study to motivate students. These badges were prepared by the researcher using visuals containing the theme of the day. However, as shown in Figure 3, the number of stars on the badges varies according to the performances of the groups after each activity. These stars also provide support for students' leadership.

Figure 3. Examples of Badges for the Marshmallow towers Event

Leadership Table. The leaderboard is a table in which players can track the rewards they have earned, such as points, access, authorization, level jump (Fiş Erümit, 2016). In the gamified STEM lesson plans made within the scope of the research, the leadership table (as depicted in Figure 4) is integrated. In this way, students can see their own points each week and learn about the status of other players.

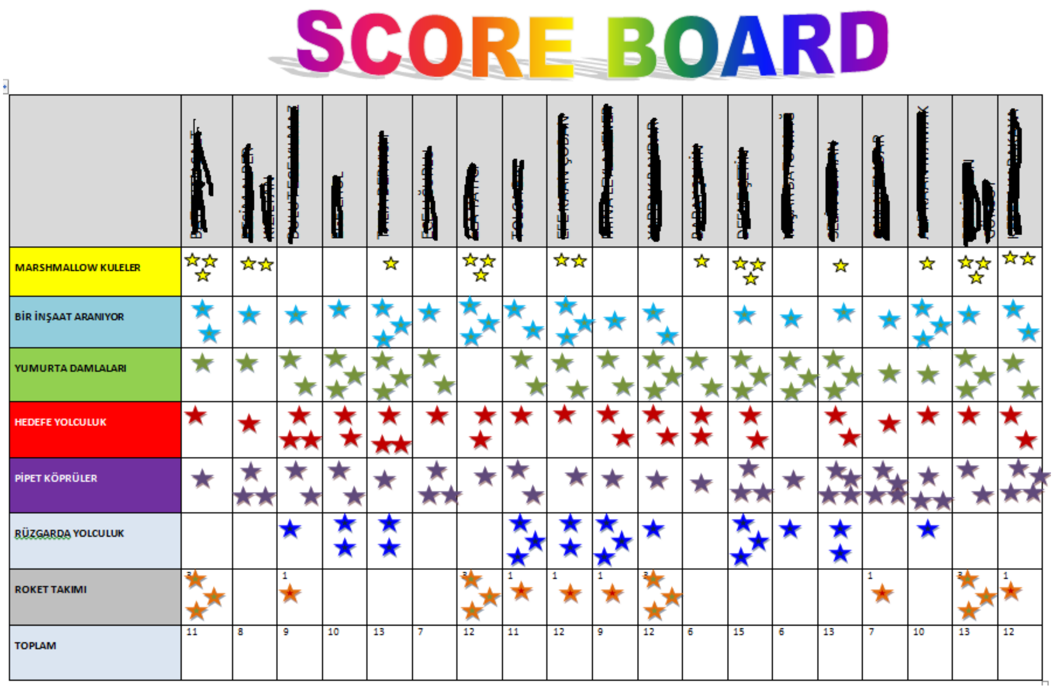


Figure 4. Leadership Table Used in Played STEM Activities

Data Analysis

As both quantitative and qualitative data collection tools were used in this study to answer the research questions, Table 2 shows which data collection tools were used to respond related research question and what data analysis methods were used. In order to check the normal distribution of problem-solving skills perception scale and critical thinking dispositon instrument, Shaphiro-Wilk test was conducted for both test and p-values of each test was found appropriate for normal distribution ($p=0.31$ and $p=0.77$ respectively).

Table 2. Research Questions and Analysis Methods

Research Question	Data Collection Tool	Data Analysis
1. Is there a significant difference between the students' pre-and-post-test scores of critical thinking dispositions when gamified STEM practices are conducted during the course?	Critical Thinking Disposition Instrument	Paired Sample t-Test
2. Is there a significant difference between the students' pre-and-post-test scores of problem-solving skills perceptions when gamified STEM practices are conducted during the course?	Problem Solving Skills Perception Scale	Paired Sample t-Test
3. What are the students' intrinsic motivation levels when gamified STEM practices are conducted during the course?	Intrinsic Motivation Inventory	Descriptive Analysis
4. What are the students' views on the practices in the course designed with the gamified STEM practices?	Semi-structured interviews, observation notes	Content Analysis Category / Codes (Thematic Analysis)

Results and Discussion

RQ1. Critical Thinking Disposition. In order to analyze the effect of gamified STEM practices on students' critical thinking skills, pre-test post-test was applied and t-test values were examined. The findings obtained are given in Table 3. According to the findings, students' critical thinking disposition pretest and posttest mean scores were analyzed statistically at 95% confidence level, a significant difference was found (p=0.01<0.05).

Table 3. Critical Thinking Disposition t-test Results

	$\overline{X}$	*sd*	*t*	*df*	*p*
Pre-test/Post-test	-4.173	7.511	-2.66	22	.014
Pre-test	99	9.79			
Post-test	103.17	13.33			

Results show that gamified STEM practices positively and significantly improve students' critical thinking disposition. Many studies in the literature supports the finding that STEM practices have a positive effect on students' critical thinking skills (Capraro & Slough, 2013; Duran & Şendağ, 2012; Mutakinati, Anwari and Yoshisuke, 2018).

RQ2. Problem Solving Skill Perception. In order to analyze the effect of gamified STEM practices on students' problem solving skills perception, pre-test and post-test were applied and t-Test values were examined and the results are given in Table 4. According to the results, students' pretest and posttest mean scores were analyzed statistically at 95% confidence level, there was no significant difference found although it was close to the significance level (p=0.057>0.05).

Table 4. Problem Solving Skills Perception t-test Results

Factor	$\overline{X}$	sd	t	df	p
Pre test – Post test	-2.60	6.23	-2.00	22	.057
Pre-test	89.65	9.42			
Post-test	92.26	11.96			

The result shows that gamified STEM practices do not have a significant difference in students' perceptions of problem-solving skills. Considering that the average score value of the scale is 80, it can be said that the students participating in the study perceive themselves sufficient in terms of problem-solving skills. Elliot et al. (2001) also concluded that there was no increase in students 'problem solving skills in their study to measure the effect of STEM education on university students' critical thinking skills, problem solving skills and attitudes towards mathematics. However, there are studies in the literature that contradict the results of the study (Pekbay, 2017; Ceylan, 2014). When the interviews and observation notes with the students are examined, it is observed that students' problem-solving abilities, even though it is a soft skill, were developed throughout the process. Although Bybee (2010) states that students can gain skills such as problem solving more easily with group studies conducted in STEM education, in this study, students had difficulty in working as a team. The reason behind this may be that they did not have much group work experience in previous courses or it might be because of their age. When the observation notes were examined, it was seen that students who had high creativity skills had difficulty in adapting with their teammates and they sometimes preferred to work alone.

RQ3. Intrinsic Motivation. When students' intrinsic motivation means and standard deviations were analyzed, the average score of interest/enjoyment was found $\overline{X}$ = 4.7, the perceived competence average was found $\overline{X}$ = 4.7, the average of effort was found $\overline{X}$ = 4.68, the average of pressure/tension was $\overline{X}$ = 3.15, the average of perceived choice was $\overline{X}$ = 3.75, and the average of value/usefulness was $\overline{X}$= 6.1. When the survey results were examined, some items were highlighted and showed below:

- 69.2% of the students stated that the activities are beneficial for him/her.
- 84.6% of the students stated that they enjoyed their activities.
- 69% of the students think that the activities are not a boring, but a fun.
- 65% of the students stated that they did not feel under pressure while doing the activities.
- 80% of the students stated that they absolutely disagree with the statement "I chose this job because I had no other choice".
- 69% of the students stated that the activities are very beneficial for them.

Doğanay (2018) and Gazibeyoğlu (2018) concluded that the courses applied with STEM approach increase the academic success of students. In addition, Öcal (2018) concluded that the STEM approach benefits students in developing scientific process skills. Although the implementation of gamification at primary school level is not recommended due to the competition environment and reward system created by the students, it is seen that it has a positive effect on the motivation of the students. Özkan and Samur (2017) analyzed and evaluated the published articles in order to determine the effect of gamification on the motivation of students in the learning process, and reached the conclusion that there was a significant difference in 7 of the 9 articles. In addition, many studies on gamification have shown that gamification has a positive effect on students' motivation (Ersoy, 2017; Hüner, 2018; Karatekin, 2017). The data obtained from the intrinsic motivation inventory and student interviews conducted for this study are in the direction that the gamified STEM activities increased students' interest and motivation. Also Mert (2018) found that the intrinsic motivation of the primary school students who made use of gamification in the lessons had higher intrinsic motivation than those who did not. In the results of the internal motivational inventory questionnaire, it was found that students' pressure and tension was low. It shows that students did their work without feeling any pressure while performing gamified STEM activities. On the other hand, in the qualitative data, the students stated that the activities were exciting and fun, but also created a sense of tension required to complete the tasks. In their study, Soares and Vannest (2013) stated that students grouped in a heterogenic learning environment may experience stress and pressure due to the different maturity levels and development levels.

RQ4. Students' views. At the end of the study, randomly selected four students were interviewed in a semi-structured way to collect the students' views about gamified STEM activities. The codes and categories of the interviews were presented in Table 5.

Table 5. Codes and Categories of Student Interviews

Categories	Codes
General evaluations of the application.	Nice
	Fun
	Fine
	Tension
Academic evaluations of the application.	Mathematics
	Science
	Social Studies
	Problem Solving
	Physics
	Experiment
Motivation and attitude evaluations.	Awards
	Star
	That the attitude has not change
Game elements	Competition
	Excitement
	Wonder
	Target

Pekbay (2017) also concludes that evaluating the studies as fun by students is important for developing students' interest in STEM areas. Besides, students have also associated the gamified STEM activities implemented in this study with mathematics, science and even physics lessons even though they are inherently given. As a result of the interviews, students stated that they gained academic gains rather than behavioral gains while performing gamified STEM activities. Students' responses to the worksheets are presented in Table 6. Besides, students' answers to each question for each activity are given with codes and their frequencies are presented below.

Table 6. Findings regarding the Answers Given by the Students in the Worksheet

Question: What kind of difficulties did you encounter while making your design?							
	ACTIVITY						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Material	3	2	0	3	2	1	2
Design	1	2	2	1	5	3	2
Lack of Prior Knowledge	1	0	0	0	1	0	1
Time	0	0	0	0	1	1	0
No difficulty	0	0	2	1	0	0	0
Question: What ways have you tried solve the difficulties you are facing?							
Material Change	3	3	3	2	2	2	2
Method Change	1	2	1	0	3	1	0
Time Management	0	0	0	0	1	1	0
No solution	1	0	0	2	2	1	0

Buckley and Doyle (2016) state that gamified activities have a positive effect on students' academic success. In the previous studies, it was seen that the most important element that motivates the students is to receive awards (Mert, 2018). In the interviews with the students, the fact that working as a group increases the probability of the final product to be successful. However, by applying the game elements such as "target", "competition", "reward" in the activities, students confirmed that STEM practices are an example of gamification. In addition, game elements such as badges, points and leaderboards are essential for students to motivate them reaching the sense of competence (Karatekin, 2017). When the literature was examined, studies were found that gamification positively affected the motivation of the students (Ersoy, 2017; Hüner, 2018).

Observation results showed that most of the students faced some challenges during the activities. Since one of the most important skills that STEM education aims to practice is problem solving skill, the STEM activities should be able to challenge students with some difficulties. When students' opinions about the difficulties they faced during the application were examined, it was found that they mostly had difficulties with the material selection. While creating their design they had to rearrange their designs after realizing that the materials they chose were not appropriate or not enough because of the material limitation. STEM project-based learning and inquiry-based learning involves the use of materials on the basis (Şahin, 2013), and it requires students to choose their own materials depending on the size and scope of the project. It is emphasized that inquiry-based learning should be carried out with a limited number of materials provided by the teachers (Şahin, 2013).

The students stated that they learned new content related with science and math, this result overlaps with other studies in the literature that reveal that STEM studies positively affect academic success (Bilekyiğit, 2018; Doğanay 2018; Sarıcan, 2017; Yıldırım & Selvi, 2017). Moreover, Ar (2016) and Hüner (2018) concluded that gamification positively affected students' academic success. Students were able to choose ways to reach the goal and create personal meanings with the experiences gained from the results and control their learning (Knowles, Holton & Swanson 2011; Merriam, Caffarella & Baumgartner 2007; Smith & Ragan, 1999). Therefore, it can be concluded that gamified STEM activities help students' gain essential 21st century skills in along with academic performance in the STEM areas.

Conclusions

There are few studies in the literature about gamified STEM, as a new concept. The number of studies in this area can be increased and its effects on different skills can also be examined in further research studies. It is thought that the implementation of such applications at different levels may yield interesting results. Similarly, research studies can be conducted with high school students in order to increase the awareness of STEM professions and to orient them in these fields. In the current study, a single pre-test post-test group was used due to limitations, however working with both experimental and control groups with more students may yield more reliable results. Within the scope of the research, a pilot study was carried out before the activities were implemented, and the duration of the gamified STEM applications, the materials to be used and the final game elements to be added were decided. For this reason, those piloting such activities can prevent potential problems.

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