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A GAME-BASED ACTIVITY RELATED TO PRIME NUMBERS

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ABSTRACT

This study examined a game-based teaching activity on "Factors and Multiples" designed for the 6th grade students. The game aims to create a differentiated and enriched learning environment targeted the curriculum standard "The students determine prime numbers using their properties. The students find prime numbers using the Eratosthenes sieve method." The game was played within two-course hours with 22 gifted students attending a Science and Art Center in Turkey. The students' learning behaviors were observed with an observation form during the game. At the end of the lesson, students were given a semi-structured interview form to get their opinions on the use of games in mathematics lessons. It was observed that the students were enthusiastic and were having fun during the game. The students explained that the game was both educational and entertaining and they expressed their wishes for more game activities to be included in the lessons.
Keywords: prime numbers, game-based learning, gifted students, teaching mathematics.

ASAL SAYILARIN ÖĞRETİMİNDE OYUN TABANLI BİR ÖĞRETİM ETKİNLİĞİ

ÖZ

Bu çalışmada ilköğretim 6. sınıf öğrencileri için çarpanlar ve katlar konusunda tasarlanmış bir oyun incelenmiştir. Tasarlanan oyun, matematik dersi öğretim programında yer alan "Asal sayıları özellikleriyle belirler. Eratosthenes (Eratosten) kalburu yardımıyla 100'e kadar olan asal sayılar bulunur." kazanımına yönelik farklılaştırılmış ve zenginleştirilmiş bir öğrenme ortamı oluşturmayı amaçlamaktadır. Oyun, Bilim ve Sanat Merkezi'ne devam eden özel yetenekli 22 öğrenciyle, 2 ders saati süresince oynanmıştır. Öğrencilerin oyun esnasındaki davranışları, oyun takip çizelgesi ile gözlemlenerek izlenmiştir. Süreç sonunda oyunların matematik derslerinde kullanımıyla ilgili görüşlerini almak için öğrencilere yarı yapılandırılmış görüşme formu verilmiştir. Oyun esnasında öğrencilerin istekli oldukları ve eğlendikleri gözlenmiştir. Öğrenciler oyunun hem eğlendirici hem de öğretici olduğunu, derslerde daha fazla oyun etkinliklerinin yer almasını istediklerini belirtmişlerdir.
Anahtar kelimeler: asal sayılar, oyun tabanlı öğrenme, özel yetenekli öğrenciler, matematik öğretimi.

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INTRODUCTION

The first thing that comes to mind for many people when it comes to mathematics is that it is “a course” of school years. A discipline that is usually considered as fearful, difficult, and boring. However, have you ever thought of how important mathematics is in your life, or where you will apply it? There are several definitions of mathematics; but the simplest one is, it is the science of patterns and orders (Goldenberg, Couco, & Mark, 1998). Mathematics is an assistant in understanding the world and a tool for developing our surroundings. Mathematics is an abstraction of the human brain and a game; a game that the mathematicians play.

In this sense, Uğurel (2008) claims that mathematics and game are not different concepts and they’re not distinct from each other. The arrangements in the games played since early childhood such as grouping the relevant ones, matching, ranking, combinations, trial and error method are some indicators of doing mathematics. In the advanced level, too, the indicators such as from concrete to abstract, reaching and commenting from simple structures to the complex structures take place in the games designed for adults as well. Therefore, it is necessary to see the game in mathematics and mathematics in the game. One of the most important similarities between mathematics and game is the rules. Just as we cannot play a game without knowing its rules, we cannot learn math without knowing its rules.

Students’ comprehension of mathematics, being able to acquire mathematical thinking, and becoming a good problem solver is only possible by sustaining mathematical processes such as understanding the problem, analyzing the situation, and developing a solution. Mathematical games have an important role in gaining these processes (Atasay & Erdoğan, 2017). In addition to the latent relationship between mathematics and games, it is possible to mention the specific benefits arising from the interaction and partnership of both concepts.

Randel, Morris, Wetzel, and Whitchill (1992), who investigated the use of games in mathematics lessons, concluded that game-based methods are superior to traditional teaching approaches in the development of mathematics achievement. Some of the results of the research studies (Aksoy, 2010; Onslow, 1990; Randel et al., 1992) that examined game-based teaching approaches are as follows:

- Games are useful in teaching different mathematical topics that require lower or higher-level thinking skills.
- Games are more effective than exercises in learning simple concepts and skills.
- Games can be used together with other teaching methods to teach complex concepts.
- Games increase students’ motivation.
- Games keep the students active during the game and increase their skills for competitiveness.
- Each game can be a part of concept development.
- Games are effective in reviewing the concepts.
- They promote the permanence of students' mathematical knowledge.
- Students' enjoyment and their confidence in mathematics may decrease over time. Games prevent this.
- Games help students develop positive attitudes towards mathematics.

The above research results show that games make a great contribution to teaching mathematics. Therefore, game-based teaching activities can be designed by combining game and mathematics.

Teaching mathematics lessons only with traditional methods may cause students to get bored and develop negative attitudes towards the lesson. It may also hinder their ability to associate the knowledge and skills they learn in school with real life. According to Baykul (2003), the main reasons for the low overall student achievement in mathematics are the teaching methods used in mathematics lessons. For these reasons, it is important to include new teaching methods to enrich the learning environment. Game-based activities might be an alternative to lessons taught by traditional teaching methods. Teachers, on the other hand, should be researchers, be creative, and should not hesitate to try out new practices in their classrooms.

In this study, the researcher designed a game that can be played in the teaching of prime numbers and investigated how the game worked in the classroom. The main goal of designing this game is to help students enjoy mathematics by developing positive attitudes towards the lesson and ensure the active participation of each student in the lesson by keeping their motivation high. The topic of prime numbers was chosen since the teacher (researcher) observed that the students had misconceptions related to this subject. For example, since the number 2 is even, it is not considered as a prime number; the number 1 is commonly confused as a prime number; and it is confused whether a number that is only divisible by 1 and itself is a prime number or not. Some findings of previous studies support these observations on prime numbers (Baştürk Şahin, Şahin, & Tapan Broutin, 2017). Some difficulties and misconceptions that students encounter regarding the prime numbers are reflected in lessons as anxiety, negativity, and prejudice. With the designed game, it was aimed to ensure active participation in the lesson by emphasizing the fun part of mathematics and to help reinforce and enrich the subject.

Teaching Mathematics to Gifted Students

The learning abilities of gifted students differ from the others. Gifted students learn new and complex information faster than less gifted counterparts (Dağlıoğlu, 2010). Because of this and other similar characteristics of gifted students, educational programs designed for these students require differentiation from the regular curriculum. In Turkey, gifted students attend to Science and Art Centers after school in weekdays or one day in weekends. Regardless of their educational environment, the students in this group need a program differentiated in line with their individual abilities, needs, and talents. (Karaduman, 2010). Several important issues should be taken into consideration while developing educational content for gifted students. One of them is the depth and breadth of the content. The content should be as wide, differentiated, and enriched as possible. The primary objectives of a differentiated program are to identify characteristics of this group, to support the development of these characteristics, and enhance them to advanced levels (Kaplan, 1986). Students who are gifted in mathematics require mathematics classes where they can get special attention. A suitable program for these students should adopt the following objectives (Johnson, 1994):

- Design a learning environment to teach gifted students as many mathematical concepts, ideas, and skills as possible.
- Educate gifted students to become creative and independent thinkers.
- Help the gifted students to realize and appreciate the beauty of mathematics.

According to Karaduman (2010) "No single material set can alone meet gifted students' needs adequately. Several sources are needed. Also, curriculum should be developed for gifted students in mathematics. People who can do this are curriculum developers, school leaders, and the teachers."(p.10). The education of gifted children in Turkey is fulfilled by formal schools and Science and Art Centers. Ministry of National Education (MoNE) conducted a workshop titled “Developing and Enriching Activities Implemented at Science and Art Centers” on June 15th, 2015, and encouraged teachers of Science and Art Centers to develop high-quality activities. The activities developed in this context can be identified as enrichment activities much more than differentiation (Akkaş & Tortop, 2015). Although there are some teaching activities developed for gifted students in recent years (Cevizci, 2018), there is still need to develop new activities in different topics. This article introduces a game-based teaching activity on prime numbers, which was designed for a Science and Art Center within the scope of enriching mathematics educational content. The activity will be beneficial for all students, whether gifted or not.

ACTIVITY IMPLEMENTATION

1. The Preliminary Study Phase

The researcher observed that the students had difficulties in understanding the prime numbers topic and forget it in a short time; thus, she searched for a practical way to enrich and reinforce the content, make the learning easier and more fun. She reviewed the related literature and examined the previous studies to find a solution for the problem.

2. The Planning Phase

At this phase, it was decided to create an educational material by combining mathematics with play, children's most favorite activity. Accordingly, a game-based teaching activity was planned.

3. Defining the Objectives

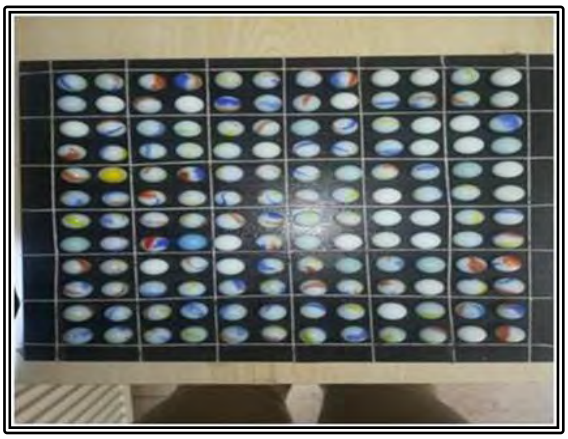
In this study, the main objectives are as follows:

- Emphasizing fun part of the mathematics.
- Decreasing negative attitudes, anxieties, and prejudices of students against prime numbers.
- Increasing the usage of original mathematics games.
- Promoting game-based activities on prime numbers topic in the field of mathematics.
- Sharing research-based educational experiences.

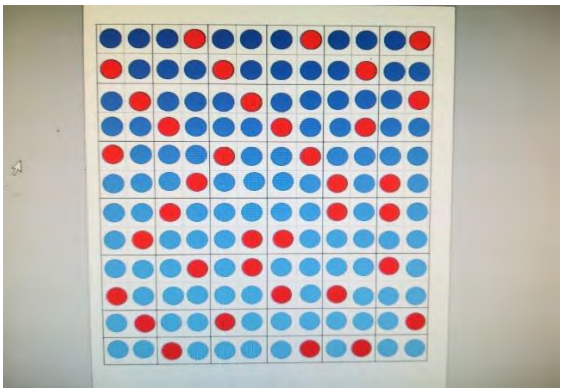
As a special objective, it is aimed to provide more robust learning by enriching and reinforcing the concept of the prime numbers.

4. Identifying Context

While forming the game template, the box games in the market were examined and then evaluated in the sense of its convenience to be adapted into prime numbers concept. Inspired by *Kakuzu* game template, which is a strategy game, the researcher herself arranged the distribution of numbers and re-planned its rules. A 12x12 template and 36 sections were used for the game. It was designed to include three prime numbers in each row and each column and only one prime number in each square section. Then, the prepared template was given to a carpenter and he was asked to turn it into a wooden plate. The plate involves 36 holes, each has a number written on it. A paper template on which the numbers are written was created on the computer and then each number was placed on the holes. The numbers were closed with marbles and these marbles were used as a game stone. The changeable template was created using numbers from 1 to 100. Numbers were distributed in a certain order: one prime number out of four numbers in each square and three prime numbers out of 12 numbers in each column and row. This pattern was used to promote combining the chance factor of early moves of the game with knowledge derived from logic and strategy at the latter moves. The picture of game board is shown in Photograph 1, game template is shown in Photograph 2. The red circles show prime numbers, the distribution of all numbers is given in Appendix 1.



Photograph 1. Game Board



Photograph 2. Game Template

5. The Implementation Phase

The game-based activity was implemented at a Science and Art Center in Bursa in 2018-2019 academic year. The participants were 22 sixth grade gifted students. Classroom size at Science and Art Centers is low and it varies based on the program that students are enrolled. For example, classrooms are consisted of 4 to 10 students at "supporting education programs," whereas "recognizing the individual abilities program" has 2 to 6 students (MoNE, 2016). Since the class sizes are low, there was no difficulty in the implementation of the game activity in terms of management. Students were divided into groups of 2 to 4 members. The reasons for

choosing gifted students are; (i) the researcher works at the Science and Art Center, (ii) the necessity to provide enriched and alternative activities other than the ones implemented at the formal schools. Before the implementation of the activity, required permissions were taken from the legal authorities.

The activity was implemented in two-class hour time. Firstly, the students were asked whether they had previously heard about prime numbers or not. Though some students connected the prime numbers with divisibility rules, they were not confident in their understanding and some of them gave incorrect responses. Before the definition of prime numbers was discussed, simple divisibility rules were presented to establish a basis for the topic. Then, the prime numbers were defined and the students detected the prime numbers at the hundreds chart by using the sieve of Eratosthenes algorithm (Photograph 3). At this pre-game stage, the students studied the prime numbers from one to a hundred.

Photograph 3. Application of Sieve of Eratosthenes

Before playing the game, the teacher explained the rules of the game to the students. The rules of the game, given in Appendix 2, can be listed as follows:

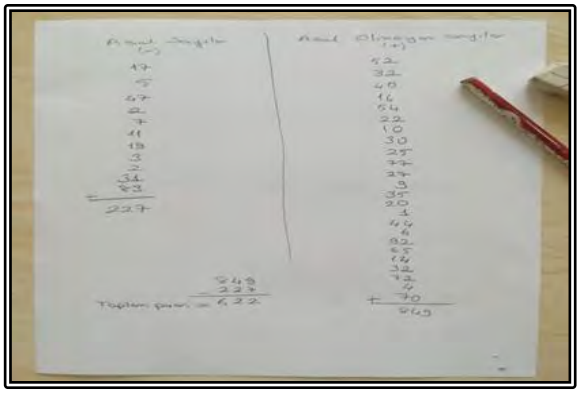
- The game can be played with a minimum of two persons or groups, and a maximum of four persons or groups.
- Players draw a number to determine who will start the game first.
- On the game board, all numbers should be covered with marble at the beginning of the game.
- The first player takes a marble and looks at the number below; if the number is a prime number, that number is added to the negative (–) section of his/her score chart; if the number is not a prime number, that number is added to the positive (+) section of the score chart.
- The players continue the game in turns by taking marbles.
- The game continues until finishing the last marble on the game board.
- At the end of the game, players / groups calculate their scores.
- The player or group with the highest score wins the game.

The teacher observed the game stage by participating in the activity both as a referee and as a researcher. She noted her observations on an observation form (Appendix 3). She gave the students time to discuss with each other whether the number drawn is a prime number or not. If the group cannot reach an agreement about the number, the referee/teacher steps in and asks whether that number can be divided by any number other than 1 and itself or not. If needed, the teacher reminded the definition of a prime number and supported the students in making a decision. This phase provided a useful learning environment for reinforcing the subject.

The game is planned for a minimum of 2, maximum of 4 players. The number of players varied depending on classroom size. Each group gave a name to their team. Players drew a number to determine who will start the game. The players took marbles taking turns and decided whether the number under the marble was prime or not. They then filled out the score charts. If the number drawn under the marble was a prime number, they lost points (the value of that prime number), if the number was not a prime number, they gained points (the value of that number). At the end of the game, the player with the highest score won the game. Furthermore, as previously stated, the prime numbers were not located randomly; at each row and column three prime numbers were located, and each square group had only one prime number inside. Students noticed this pattern and used this strategy to win the game. They removed the marbles according to a strategy, not at random. The game finished with the announcement of the winner student with the highest score. Photographs 4, 5, and 6 show the game stages.

Photograph 4. Students Complete the Score Chart

Photograph 5. An Image from the Game



Photograph 6. Sample Score Chart

6. Assessment of Implementation Phase

A questionnaire consisting of five open-ended questions was prepared by taking the opinions of experts. This form was used as the semi-structured interview form to obtain the views of students on the game-based activity. The questionnaire is given in Appendix 4.

In the first question, the students' opinions, feelings, and thoughts were asked regarding the lesson. Out of 22 students who completed the activity, four of them considered the lesson was "good," four students considered "good and enjoyable," eight of them considered "informative," four students considered "enjoyable and informative," and two of them considered "good, enjoyable, and informative." For example, one student wrote "I think the lesson was very good, if we play these kinds of games, the lessons will be more enjoyable and help us learn permanently." (Figure 1).

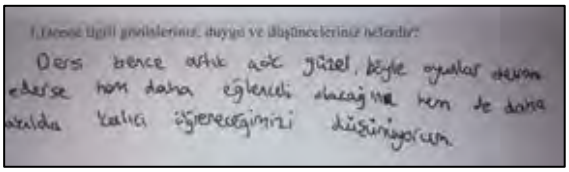


Figure 1. A Student's Answer to the First Question

In the second question, all of the 22 students stated that the game activity helped them learn prime numbers. They expressed that while discussing whether a number is a prime number or not, they enjoyed it and this practice helped them understand the subject better. A sample student response is given in Figure 2.

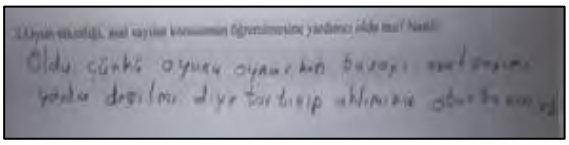


Figure 2. A Student's Answer to the Second Question

The students were asked, whether they had ever thought of learning mathematics through games; 10 of them answered "no," and 10 of them answered "yes." When they were asked if they had ever played games in their previous mathematics classes; 13 of them answered "no," two of them replied "we used brain and mind games, but not directly related to mathematics," and seven of them replied "yes." Figure 3 shows the response of a student who explained that he experienced playing games in mathematics lessons at the Science and Art Center and he thought that it was a great learning experience.

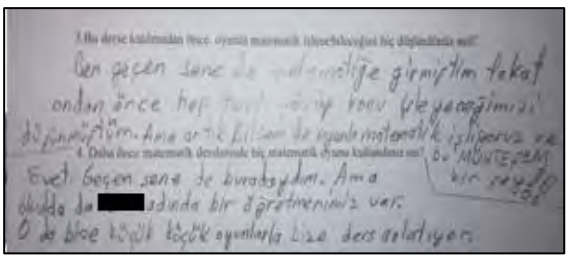


Figure 3. A Student's Answer to the Third and Fourth Questions

In the fifth question, the students were asked whether they want to play educative games in their mathematics lessons. All students answered "yes" to this question. Eight students explained that playing mathematics games is "enjoying," eight students wrote that it is "entertaining and instructive," and six students stated that it is "instructive." A sample answer is given in Figure 4.

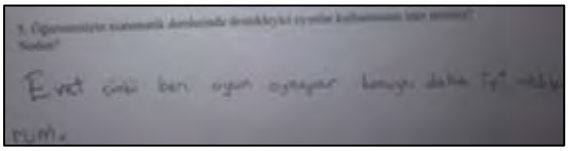


Figure 4. A Student's Answer to the Fifth Question

During the game-based activity, the teacher filled an observation form to determine the goal attainment levels of the students. She graded students' performance based on her observations. Based on this list, six criteria were evaluated at four levels: "low - 1," "medium - 2," "good – 3," and "very good – 4." With this observation list, it was also aimed to observe the lesson process in an organized way. After evaluating all of the students, the arithmetic means were calculated. Three and upper scores for each group are considered successful fulfillments for these six criteria. According to Table 1, all groups successfully completed the game-based activity.

Table 1. Students' Performance Based on the Observation Form

Criterion		**Low**	**Medium**	**Good**	**Very Good**	
Mean	n	*f*	*f*	*f*	*f*	$\overline{X}$
1. Examined the materials before starting the game and learned their function.	22	0	4	10	8	3,18
2. Listened to rules carefully before the game.	22	0	5	9	8	3,59
3. Followed the rules during the game.	22	0	3	11	8	3,22
4. Determined and used a strategy during the game.	22	1	4	10	7	3,05
5. Each student calculated his/her own total score.	22	0	2	10	10	3,36
6. Completed the game with patience and played along with each other.	22	1	4	8	9	3,13

CONCLUSION and SUGGESTIONS

This study was conducted with 22 sixth grade students at a Science and Art Center and aimed to teach them prime numbers with an effective, enjoying, and enriched game-based activity for a better reinforcement. Since the study was performed at a Science and Art Center with small groups, no significant problems were encountered in terms of behavior management. For more crowded classrooms, teachers may form groups of four students maximum and increase game templates. In the current implementation, the game helped students engage in reasoning and strategic thinking therefore it would also be suitable for mind game classrooms at schools. The participating students expressed that they enjoyed the game a lot and they even didn't want to take a break. It is widely known that the games have several positive contributions to students such as making them active and helping them learn mathematics concepts (Onslow, 1990).

Games are essential for the children at the primary school ages. In this sense, if the teachers produce and use game-based activities and include them in the curricula, this may increase students' motivation for learning mathematics and mathematics achievement (Aksoy, 2010). Likewise, further utilization of differentiated and enriching mathematics activities for gifted students is crucial. The game-based activity shared in this article will be an effective and useful teaching material for teaching the concept of prime numbers. If teachers share and disseminate similar

differentiated activity samples, this will further contribute to the education of students at different ability levels.

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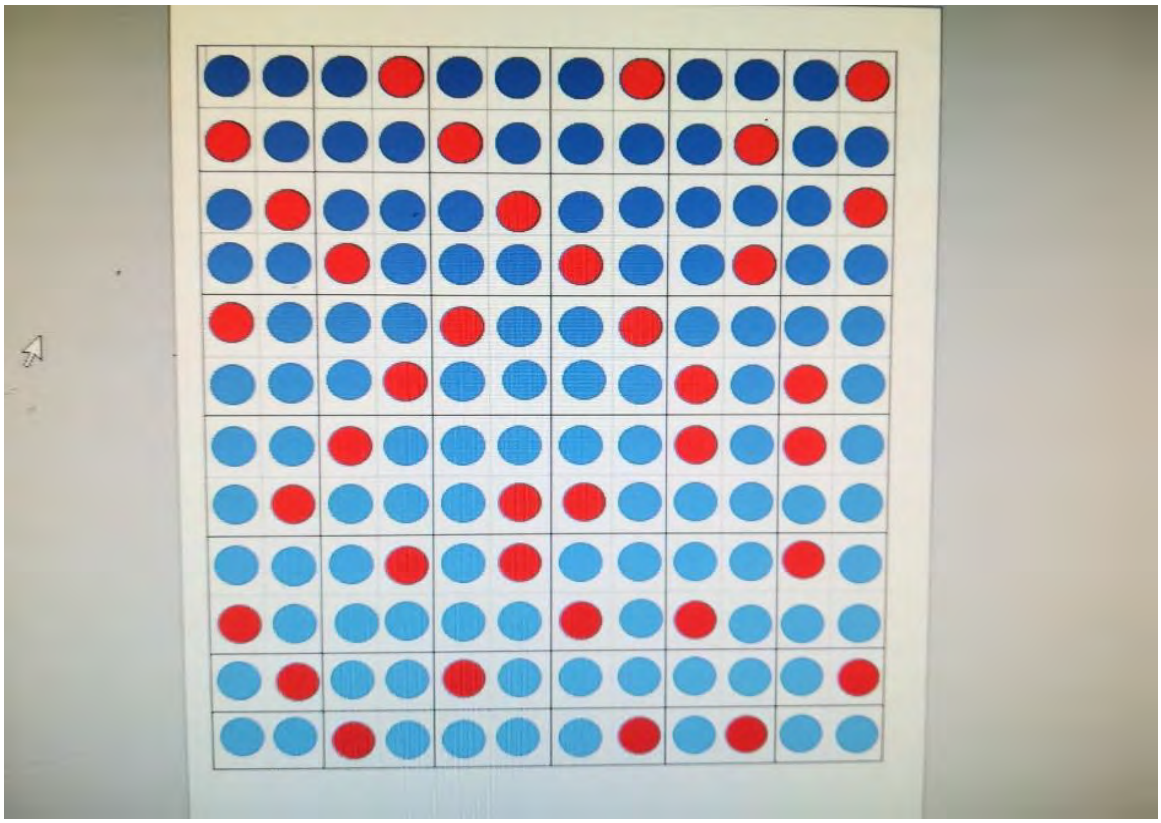
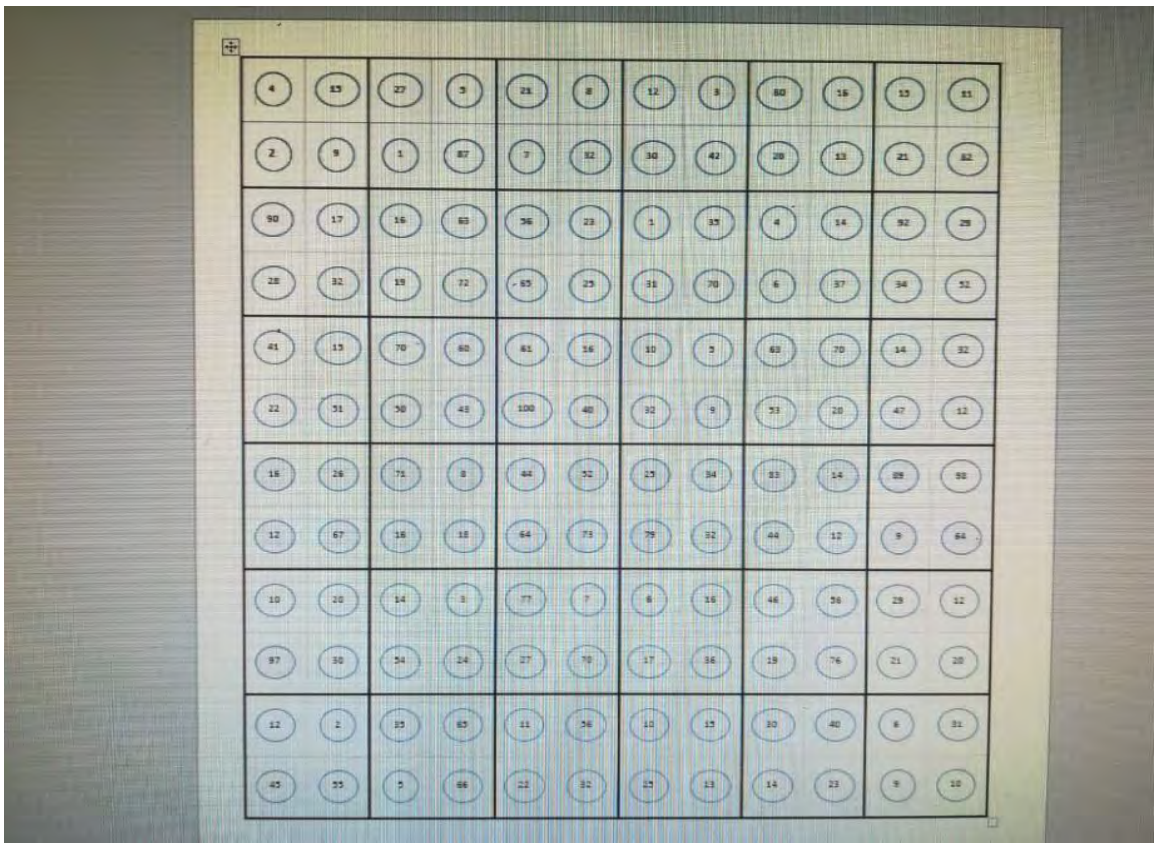
Appendix 1

Sample Game Templates





Appendix 2

Rules of the Game

1. The game can be played with a minimum of two persons or groups, and a maximum of four persons or groups.

2. Players draw numbers to determine who will start the game first.

3. All numbers on the game board should be covered with marbles at the beginning of the game.

4. The first player takes a marble and looks at the number below. If the number is a prime number, that number is added to the negative (–) section of his/her score chart, if the number is not a prime number, that number is added to the positive (+) section of the score chart.

5. The players continue the game in turns by taking marbles.

6. The game continues until finishing the last marble on the game board.

7. At the end of the game, players or groups calculate their scores.

8. The person or group with the highest score wins the game.

Appendix 3

Game Observation Form

Name of the Student: Group ID:	Low	Medium	Good	Very Good
1. Examined the materials before starting the game and learned their function.				
2. Listened to rules carefully before the game.				
3. Followed the rules during the game.				
4. Determined and used a strategy during the game.				
5. Each student calculated his/her own total score.				
6. Completed the game with patience and played along with each other.				

Appendix 4

Prime Numbers Game Activity Student Opinion Questionnaire

1. What are your opinions, feelings, and considerations of the lesson?

2. Did the game activity help you to learn the concept of prime numbers? How?

3. Have you ever thought that it was possible to learn mathematics with a game before attending this class?

4. Have you ever used mathematics games in your mathematics lessons?

5. Do you want your teachers to use supplementary games in mathematics lessons? Why?