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The impact of activity-enriched teaching and educational games on the academic success of middle school students in astronomy courses

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Abstract

This study investigates the effect of teaching enriched with astronomy activities and educational games on astronomy achievement in the 6th-grade Solar System and Eclipses unit. Fifty-seven students in the 6th grade of a secondary school in Türkiye participated in the study. Although the groups were formed randomly, since the students themselves could not be randomly distributed among the groups, a quasi-experimental design with pre-test and post-test control groups was adopted. The experimental group used a constructivist learning approach and educational games and activities related to the astronomy course. The control group used only the constructivist learning method. While creating the astronomy achievement test as a data collection tool for the research, the achievements of the 6th-grade Solar System and Eclipses Unit were considered. Validity and reliability studies were conducted for the data collection tool, and it was concluded that the test was applicable. The experimental application revealed that including astronomy activities and educational games in science lessons increased the astronomy achievement of 6th-grade students. Based on this result, it can be said that educational games and activities used in science lessons can positively contribute to achievement.

Keywords: Activity-based learning, Astronomy achievement, Astronomy teaching, Game-based teaching, Science education, Science teaching.

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Contents

Contribution of this paper to the literature
In the study, the effect of teaching enriched with astronomy activities and educational games on astronomy achievement was investigated, and it was concluded that it was effective for students' astronomy achievement. It is thought that astronomy activities and games will contribute to the literature by providing a different alternative perspective.

1. Introduction

Developing science and technology constitute the basis of contemporary life. As science and technology continue to advance, expectations from individuals also evolve. Recent studies indicate that a modern education system is increasingly reliant on digital technologies (Singh, 2021). In today's world, individuals are expected to solve the problems they encounter, demonstrate strong communication skills, show entrepreneurship, generate knowledge, empathize, make decisive choices, and contribute positively to society. This development is possible by following a planned process, gaining desired behaviors in the individual, and adding new behaviors to the individual through experience. Although this process is not only carried out in schools, every place where individuals can participate in desired behaviors is considered an educational home (Wilhelm, Toland, & Cole, 2017). Education is regarded as a fundamental pillar for the advancement of society. Consequently, educators play a crucial role in shaping the future (Güven & Özerbaş, 2016).

In addition to the use of three-dimensional materials and educational games, online games and activities, along with portable mobile devices such as smartphones and tablets, contribute to the advancement of education. These tools enable the individualization of learning, allowing it to be tailored to students' specific needs and making education accessible anytime and anywhere (Chen, Chang, & Wang, 2008). These learning environments, which are evaluated within the scope of maintaining teaching and learning processes through online and mobile environments, are defined as learning that is carried out using internet access and mobile technologies, supports individual learning, and provides the opportunity to participate in education at any place and time (Sharples, Taylor, & Vavoula, 2007; Wang, Wu, & Wang, 2009).

Based on these and similar definitions, it is known that online and mobile learning is an important advantage in providing flexibility in accessing educational content and increasing retention, as well as teaching lessons with activities and games. Learning environments created with activities and games in education, along with online tools, increase academic success by enhancing motivation (Demir & Akpinar, 2018; Sarrab, Al-Shihi, Al-Manthari, & Bourdoucen, 2018), providing time and space flexibility and accessibility for learning (Han & Shin, 2016), and making learning more enjoyable (Kose, Koc, & Yucesoy, 2013).

Entertainment elements in the learning process provide important features for students regarding relaxation and intrinsic motivation (Prensky, 2001). Thanks to these features, games provide students with fun and pleasure and increase participation (Şenel & Akman, 2016). Even a student who is not interested in the subject, who is bored with lessons and impatiently waiting for the end of the lesson, can participate in a game played in the classroom environment (Tsay, Kofinas, Trivedi, & Yang, 2020). In-class games and activities have the potential to capture students' attention and support the achievement of teaching goals (Garris, Ahlers, & Driskell, 2002). Entertainment components in educational games ensure that the intended learning objectives are achieved and encourage participation (Perttula, Kiili, Lindstedt, & Tuomi, 2017).

The numerous abstract concepts in science, an integral part of education, can influence students' perception of the subject and diminish their motivation to learn (Çavuş & Balçın, 2017). While preparing the education and training environment, especially at the secondary school level, since the abstract concept period has not yet fully passed, concretizing the concepts will facilitate students' learning and make them more active (Kaya & Elgün, 2015). Teachers should use educational games to help students improve their attitudes toward science courses (Demir, Öztürk, & Dökme, 2012).

Activity-based learning, which has constructivist aims, offers several activities to students based on the principle of 'learning by doing and experiencing.' While preparing the activities applied in activity-based learning, the principle of simple to complex is taken as a basis (Macdonald & Twining, 2002). Sixth-grade students are interested in and curious about games, considering their age and developmental characteristics. Therefore, educational games can be used at this age level (Coşkun, Akarsu, & Kariper, 2012; Suydam & Higgins, 1977). Students will learn science concepts more quickly because they will enjoy playing the games (Aksoy & Baran, 2020). The educational game to be prepared is applied by the target acquisitions in a way that covers the whole class. The teacher follows this process (Korkmaz & Öztürk, 2020).

In-class educational games have been found to enhance creativity, offer students opportunities for socialization and collaboration, and boost their self-confidence (Bağcı, 2011). Students are motivated to analyze information, attain profound and significant learning experiences, and actively engage in their own educational journey (Kyriacou, 1992; Uğraş, 2024). This highlights that educational games possess the ability to influence student behavior, fostering lasting learning experiences (Sneider, Bar, & Kavanagh, 2011).

Astronomy-related subjects are included in the lessons starting from the 4th grade. Since astronomy is a branch of science that teaches individuals to think logically and correctly, it is known to play an active role in popularizing science among students (Taşcan & Ünal, 2015). For these reasons, students should be taught astronomical concepts in a way that makes sense to them. The correct teaching of science subjects, which are related to daily life, positively affects an individual's future. Since many university departments (Science, Physics, Engineering, Space Sciences, etc.) offer courses that include astronomy subjects, the better the subjects related to astronomy are learned at an early age, the better the scientific knowledge and retention of this knowledge will be. Therefore, conducting this study with secondary school students to explore the impact of a teaching method enhanced with astronomy activities and educational games on astronomy topics is believed to add valuable insights to the existing literature.

1.1. Significance of Research

When the concepts in the science course are analyzed, it is observed that there are many abstract concepts. Students often have difficulty grasping and learning these abstract concepts, which causes them to disengage from science lessons and affects their attitudes and performance (Moralı, Köroğlu, & Çelik, 2004). This study aims to help students learn astronomy subjects and concepts in the science course better, to concretize abstract concepts, to increase their curiosity towards astronomy subjects, and to enhance their success in science. For this purpose, activities and educational games that students would enjoy doing and playing were developed. When the literature is examined, it is important for the study that no research includes astronomy activities and educational games together with secondary school students. These developed astronomy activities and educational games will contribute to the literature and teachers by providing a new perspective. Thus, enabling students to approach science will remove teaching from monotony and provide learning through enjoyment.

1.2. Research Questions

1. Is there a notable difference in the pre-test academic performance between the group that received lessons incorporating activities and educational games and the group taught with conventional methods?

2. Is there a significant statistical difference in the mean academic achievement scores of 6th-grade students before and after being taught the 'Solar System and Eclipses' unit using astronomy activities and educational games?

3. Is there a meaningful change in the average achievement scores of sixth-grade students who studied the 'Solar System and Eclipses' unit using traditional methods, comparing their scores before and after the lesson?

4. Does a notable difference exist in the post-test achievement scores of students taught using educational games and activities compared to those taught with traditional methods?

2. Literature Review

Activity-based learning, which has constructivist aims, offers several activities to students based on the principle of 'learning by doing and experiencing.' While preparing the activities applied in activity-based learning, the principle of simple to complex is taken as a basis (Macdonald & Twining, 2002). It is an approach in which the student actively participates in learning and learns through student-centered activities (Kyriacou, 1992). A literature review reveals very few educational games specifically designed around astronomy topics. However, there are studies in which the supplement of astronomy-related activities is examined. For example, Türk and Kalkan (2017b) aimed to measure the effect of astronomy lessons with observatory activities in their study titled 'Teaching Basic Astronomy Concepts in Primary Education.' The study utilized a research design that involved a comparison between groups, where the experimental group participated in lessons that included activities at observatories. According to the results, astronomy lessons in observatories were more effective than astronomy lessons in traditional classroom environments. Şirin and Metin Peten (2020) found that the activity-based astronomy course increased pre-service teachers' achievement scores and their confidence in their astronomy teaching skills. Meanwhile, in another study, Düşkün and Ünal (2020) developed model-based activities for 60 students enrolled in 4th-grade science teaching courses. The findings indicated that the average astronomy achievement scores of the intervention group were markedly higher compared to those of the group taught with traditional methods. Yılmaz and Canbazoğlu Bilici (2017) conducted the study titled 'The Effect of QR Codes on 7th Grade Students' Attitudes Towards Science and Technology' with the participation of 23 students. The researcher developed QR codes and games for the one-month study in which a one-group pretest-posttest experimental design was used. Although no notable change was detected in students' attitudes towards science and technology, a significant positive shift was observed in their perceptions of QR code-based games. Zurnacı (2015) conducted his study titled 'Astronomy Applications in Science Education' with a branch of secondary school students. The study revealed that students' participation in astronomy activities through specially designed applications contributed to their perceptions and attitudes towards experimentation. Okulu and Oguz-Unver (2021) revealed that the developed activities related to astronomy positively affected the students. In another study, Türk and Kalkan (2017a) created an 'applied' model for astronomy teaching in a secondary school in their research titled 'Effectiveness of Astronomy Teaching with Models.' The results showed that the 'hands-on' model was effective, while the current program had a limited effect on teaching astronomy concepts. Kaya and Elgün (2015) 'Solar System and Beyond: Determination of the Effectiveness of Technology-Supported Guidance Materials Developed According to the Principles of Cognitive Load Theory for the Space Riddle Unit' used a quasi-experimental research method. An approach combining qualitative and quantitative data was used in the study. The researcher obtained data using Achievement Tests, Recall Tests, Cognitive Load Scales, and Student Opinion Questionnaires. Materials designed according to cognitive load theory were applied in the experimental group, whereas the control group used standard curriculum materials. The results indicate that students in the experimental group demonstrated more efficient learning and experienced less cognitive load than those in the control group. In his research titled 'The Impact of Technology-Enhanced Astronomy Lessons on Students' Conceptual Comprehension, Interest, and Attitudes,' Başcı (2019) carried out a study involving 4th-year students from the Science Teacher Education program. The findings revealed that the technology-supported astronomy course significantly improved pre-service teachers' conceptual understanding, interest, and attitudes. Albayrak, Yalçın, and Yalçın (2017) explored how the station technique influenced the academic achievements and perspectives toward astronomy of 7th-grade students in secondary school. The results indicated a notable improvement in the performance of the experimental group compared to the control group. In contrast, no significant change was found in attitude scores. Subaşı (2018), in his study titled 'Evaluation of Science Students' Views on Astronomy Enriched with Activities,' worked with 28 students studying in the 4th grade of the Department of Science Teaching. The results showed an increase in students' interest at the end of the course. The data showed that astronomy education enriched with activities can increase students' success in astronomy courses. Kaya (2018) investigated the teaching of basic astronomy concepts to preschool children through activities in his study titled 'Investigation of Teaching the Moon Concept to 48–60-Month-Old Preschool Children.' Data were obtained from student drawings. It was found that children's first drawings of the Moon contained inaccuracies, but they were able to learn the basic properties of the Moon through age-appropriate activities. Data analysis showed that students' attitudes towards

astronomy and motivation towards science learning improved positively. Finally, Balcı (2018) conducted a study on the Solar System Unit with Webquest-Supported Activities with 56 secondary school students. A quasi-experimental design was used. The results showed that Webquest-supported activities significantly improved student achievement in the unit, but there was no significant change in their attitudes towards astronomy. In Başakçı (2018), a study was conducted to explore how planetarium-based teaching influenced middle school students' grasp of astronomy concepts. Seventh-grade students participated, and they were split into two groups: one group received instruction through conventional methods, while the other was taught using an alternative approach. In contrast, the experimental group attended the lessons with the traveling planetarium introduced one week after the end of the unit. The findings indicated that the traveling planetarium had a more significant impact compared to the conventional teaching method. Although the experimental group showed higher attitude scores, they were not significant.

3. Method

3.1. Research Design

This research explored the impact of incorporating astronomy-based activities and educational games into lessons on the academic performance of 6th-grade students in astronomy topics. In the experimental group, educational games and astronomy activities were applied using the constructivist learning approach, while only the constructivist learning approach was used in the control group. After the implementation, the study assessed whether there was a difference in the achievement scores between the experimental and control groups. In the study, a quasi-experimental design with a pretest-posttest control group was used. Experimental research designs are the most appropriate method to test the cause-effect relationship between certain variables (Neuman, 2013). Although there are some similarities between experimental research design and quasi-experimental research design, there are differences in the selection of groups. In quasi-experimental designs, participants are not randomly assigned. A quasi-experimental design is preferred in cases where the experimental design cannot be applied because random assignment is not made (Büyüköztürk, 2001). The pretest-posttest quasi-experimental design can be used especially in studies such as developing and implementing a new educational model (Creswell, 2012). An experimental approach was employed to evaluate the impact of teaching methods enriched with astronomy activities and educational games on science achievement, incorporating both experimental and control groups. This research is classified as quasi-experimental because the students could not be randomly allocated to the control and experimental groups due to the varying course schedules in the public school where the researcher works. Instead, the pre-existing groups were randomly designated as control and experimental groups (Karasar, 2016). The groups are measured with dependent variables twice, before and after the application. The pattern is related since the same people are measured with dependent variables both before and after the application. Nonetheless, this approach is not entirely relevant because the experimental and control groups being compared in these assessments are composed of different participants. As a result, the experimental setup with a pretest-posttest in Group 1 is also classified as a mixed-method design (Howitt & Cramer, 2011). The pretest-posttest control group experimental design offers two key benefits. Firstly, since the measurements are made in the same study group, the error will decrease, and the statistical power will increase because the relationship will be high. Secondly, it saves time since the procedure is performed on the same subjects (Ferguson & Takane, 1989). A simple random sampling method was used to select the groups. The research is quasi-experimental since the students cannot be selected for the groups by randomization or lottery, and the most suitable school is used (Cohen, Manion, & Morrison, 2000).

3.2. Research Study Group

This research was conducted with sixth-grade students attending a secondary school operating under the Ministry of National Education in Turkey.

Two classes were selected from the sixth-grade students by random assignment. From these classes, one class was selected as the control group (Group 1), and the other class was selected as the experimental group (Group 2). In this respect, the sampling method of the study is convenience sampling.

Table 1. Frequency and percentage distributions of the students participating in the study.

Gender	Experimental		Control	
	n	%	n	%
Female	14	48.3	12	42.9
Male	15	51.7	16	57.1
Total	(n=29)		(n=28)	

Table 1 shows the distribution of students according to their gender. A total of 57 students studying in the 7th grade of a secondary school participated in the study. There were 14 girls and 15 boys in the class selected for Group 2, and 12 girls and 16 boys in the class selected for Group 1. The researchers conducted lessons for Group 2 and Group 1 during the research process. Group 2 was taught the 'Solar System and Eclipses' unit using the constructivist learning approach, educational games, and astronomy activities, while Group 1 was taught using only the constructivist learning approach. In other words, while the same curriculum was applied to Group 2 and Group 1, the lessons of Group 2 were enriched with educational games and astronomy activities.

3.3. Data Collection Tool of The Research

In the study, in order to determine the effect of the experimental process, the questions, including the achievements of the 6th grade 'Solar System and Eclipses' unit, were prepared by the researcher for Group 2 and Group 1 by creating a specification table. Achievement test: 50 multiple-choice questions were prepared by the researchers in terms of reducing the chance factor, being suitable for measurement and evaluation, and being easy to read. In order to use the prepared achievement test, a preliminary application must be made. During the pilot study, the test's reliability coefficient was determined, leading to the elimination of 17 questions that did not meet the

criteria of the item analysis. The prepared test was edited by taking the opinions of two academicians and three teachers. As a result of the arrangements made, the Astronomy Achievement Test, consisting of 33 items, was prepared to ensure content validity.

For the final version of the Astronomy Achievement Test, the maximum score was 33, and the minimum score was 0. The Astronomy Achievement Test, used as a pre-test and post-test in both groups, was administered to 135 seventh-grade students, and the Kuder-Richardson 20 Reliability Coefficient of this achievement test was calculated to be 0.87. In addition, the item difficulty index of the test was found to be 0.55. The item difficulty value is generally expected to be around 0.50. Furthermore, simpler or more difficult items can be included in the tests (Büyüköztürk, 2019). The Astronomy Achievement Scale was applied to both groups as a pre-test and post-test to determine whether there was a difference between Group 2 and Group 1 regarding astronomy achievement.

3.4. Data Collection Process of the Research

Before the experimental study, astronomy activities and educational games were prepared by reviewing the literature. In Group 2, astronomy activities and educational games, which were prepared differently from the activities in the curriculum, were added to the lesson plan after receiving expert opinions. While implementing astronomy activities and games, explanations were provided. For the control group, lessons were taught using only a constructivist learning approach. Before the application, the Astronomy Achievement Test was administered as a pre-test, allowing sufficient time for the groups and creating suitable environmental conditions. After the application, the test was administered to the groups again.

3.5. Analyzing the Data

This research explored how incorporating astronomy-based activities and educational games into the 6th grade 'Solar System and Eclipses' unit impacted students' performance in astronomy. The achievement test created by the researchers was used to collect data from the groups at the beginning and end of the study, and the data were analyzed using '1' for correct answers and '0' for incorrect answers. The information collected during the study was processed and evaluated using a statistical software package.

Table 2. Analysis of normality distribution for the astronomy achievement test.

Tests	Group	N	X	S	Median	Mode	Kurtosis	Skewness	Shapiro-wilk
Pretest	Control	28	12.14	3.47	12.5	13	-0.610	-0.078	0.928
	Experiment	29	12.07	3.32	12	12	-0.533	0.263	0.812
Posttest	Control	28	21.5	3.59	21.5	20	-0.661	-0.358	0.303
	Experiment	29	26.38	5.45	28	30	1.42	-1.187	0.09

Table 2 shows the analysis of normality distribution for the astronomy achievement test. According to this, the post-intervention scores of Group 1 and Group 2 in the academic achievement test are higher than their pre-intervention scores. In order to determine whether this difference between the averages was statistically significant, it was checked whether the data were normally distributed. If the sample size is more than 35, the Kolmogorov-Smirnov (K-S) test (McKillup, 2012) can be used, and if it is smaller, the Shapiro-Wilk test (George & Mallery, 2010) can be used. Shapiro-Wilk, kurtosis, and skewness coefficients were used to evaluate the normal distribution of the data. When the data in the table are examined, it is seen that the skewness and kurtosis coefficients of the achievement test pre-test and post-test scores of both Group 1 and Group 2 are between -1.5 and +1.5, and the mode, median, and arithmetic mean values are close to each other. The significance values of the Shapiro-Wilk analysis are greater than 0.05. According to existing literature, variables with kurtosis and skewness values ranging from +1.5 to -1.5 (Shapiro & Wilk, 1965; Tabachnick & Fidell, 2013) are generally considered to follow a normal distribution. In addition, the arithmetic mean, mode, and median being equal or close to each other in the distribution is shown as evidence of the normality of the data (Lind, Marchal, & Wathen, 2006; McKillup, 2012; Wilcox, 2012). This shows that the pre-and post-test data are normally distributed. Based on the findings, the research data were analyzed using parametric tests. In this context, t-tests for both dependent and independent groups, which are appropriate for normally distributed data, were applied during the analysis process.

3.6. Ethical Information

The ethical suitability of this research was examined by the Gazi University Ethics Committee in Turkey at its meeting dated September 7, 2021. The research was found to be ethically appropriate with the decision numbered 2021/930. The study group was informed in detail about the analyses to be performed and the outputs of the results before the study, and signed informed consent forms were obtained from them.

4. Results

The study explored whether there were variations in the achievement levels before and after the intervention for the group receiving astronomy activities and educational games, and similarly, for the group taught through conventional methods.

Table 3. t-test results for the pre-test achievement scores of the groups.

Group	N	X	S	Df	T	P
Control	28	12.14	3.47	55	0.082	0.935
Experiment	29	12.06	3.3			

According to Table 3, the mean pre-test score of the students in the 2nd group before the experimental application was X=12.06, while the mean pre-test score of the students in the 1st group was X=12.14. ($t_{(55)}$ =0.082; $p > 0.05$). Therefore, it can be said that there is no significant difference between the mean pre-test achievement scores of Group 2 and Group 1. This finding shows that the variances are homogeneously distributed; that is, the

groups are equal in terms of achievement.

Table 4. Results of the t-test for the pre-test and post-test scores of the control group students.

Group	N	X	S	Df	T	P
Pretest	29	12.07	3.31	28	-12.66	0.000
Posttest	29	26.38	5.45			

Table 4 shows the t-test results for the pre-test and post-test scores of the control group students. When the scores of the students in Group 2 before and after the application are compared, it is understood that there is a significant difference: $t_{(28)}$= -12.66; p<0.05. This finding indicates that the intervention successfully contributed to enhancing academic performance. The effect value of the application was found to be 0.73.

Table 5. t-test results of the pretest and posttest achievement scores of the experimental group students.

Group	N	X	S	Df	T	P
Pretest	28	12.14	3.47	27	6.66	0.000
Posttest	28	21.50	5.90			

Upon examining Table 5, it was observed that the academic performance of Group 1 students, who were taught using the current curriculum, showed an improvement. The average achievement score of Group 1 students increased from X=12.14 prior to the instruction to X=21.50 following the instruction. $t_{(27)}$=6.66, p<.05. This situation shows that the success of the students who are educated using the current teaching method has increased. The eta-square value was calculated for the findings obtained and found to be 0.62. Cohen's d value was found to be 1.25.

Table 6. t-test results of the groups' post-test achievement scores.

Group	N	X	S	Df	T	P
Control	28	57.75	5.76	55	-3.11	0.003
Experiment	29	62.38	5.45			

Table 6 shows that after the six-week intervention, a significant difference was found in the achievement scores of students who received instruction through astronomy activities and educational games compared to those who were taught using the traditional method ($t_{(55)}$ = -3.11; p< 0.05). It was found that the students in Group 2 outperformed those in Group 1 in terms of achievement scores. This shows that the application is effective in increasing students' achievement. The effect size value for the obtained data was found to be 0.14.

5. Conclusion

The results of the data obtained from the research are presented below.

The first question of the research is to examine whether there is a difference between the students who take lessons enriched with activities and educational games and the students who take lessons with traditional methods in terms of pre-test achievement. An independent samples t-test was used to examine this. The analysis showed that there was no significant difference between the pre-test results of the two groups. This outcome implies that the initial academic performance of students in both groups was similar, with both groups demonstrating homogeneous variance.

The second question of the research examines whether there is a significant change in the achievement scores of sixth-grade students using astronomy activities and educational games related to astronomy by comparing their scores before and after the application. A dependent samples t-test was applied to assess this change. The analysis revealed a significant improvement in students' achievement scores after applying these enriched teaching methods.

The third question explores whether there is a significant difference in the mean achievement scores of 6th-grade students taught with the traditional method in the same unit, comparing their scores before and after the teaching intervention. A dependent samples t-test was used to analyze this question as well. The findings revealed a notable rise in achievement scores following the implementation of traditional teaching methods with the students.

The last research question analyzes the post-test mean scores of the group educated with activities and educational games and the group educated with traditional methods. This data was analyzed using a t-test for independent samples. After six weeks of the experimental procedure, the results indicated a significant difference in the achievement scores, favoring the group taught with astronomy activities and educational games. These findings suggest that employing enriched methods to teach the Solar System and Eclipses unit significantly enhances student performance.

6. Discussion

An evaluation of the post-test results revealed a noticeable distinction between the two groups despite the lack of significant differences in their pre-test scores. The findings favored Group 2. Specifically, according to the study's conclusion, students in Group 2—who were taught using a combination of the constructivist learning approach, educational games, and astronomy activities—achieved significantly higher scores than students in Group 1, where only the constructivist learning approach was employed. When the pre-test and post-test scores were examined within each group, both groups exhibited improvement; however, the increase observed in Group 2 was more pronounced than that in Group 1. It is thought that educational games help students focus on the subject and increase their motivation, and this situation provides more effective learning (Eltem & Berber, 2020). In this study, the researchers also observed that the students in Group 2 participated in the lesson with interest and had a high level of motivation. The research findings revealed that the activities in Group 2 were more effective in science teaching than using curriculum-based teaching alone. The fact that games appeal to multiple sensory organs, contain concrete materials, and encourage student interaction plays a major role in this process. Considering all the findings, it can be inferred that the experimental approach led to an improvement in the students' performance, and it can be said that

the application also contributed to the students' interests and creativity. In support of this study, Kayabaşı and Akbaş (2017) revealed in their research that the subjects learned with educational games effectively increase students' achievement. Öztürk and Korkmaz (2020) and Yılmaz and Canbazoğlu Bilici (2017) concluded in their research that learning by doing and experiencing educational games positively affects students. Düşkün and Ünal (2020) conducted activities using models for pre-service science teachers and concluded that the activities caused a significant increase in students' achievement scores. Similarly, Okulu and Oguz-Unver (2021) examined how astronomy activities influenced the knowledge of pre-service science teachers and found that these activities led to a substantial improvement in their understanding of the subject.

When the science textbooks taught in schools were examined by researchers, it was observed that games were not included much (Eltem & Berber, 2020). Therefore, in cases where the curriculum is insufficient, teachers can help increase students' motivation and achievement levels by occasionally playing educational games related to the subject. Considering that children enjoy games at a young age and spend most of their time playing them, it is recommended to use educational games while teaching units containing abstract concepts such as astronomy. Thus, students can learn the subject willingly and fondly. Since games boost engagement and enthusiasm, they can help involve introverted students and those with learning challenges (Charlton, Williams, & McLaughlin, 2005). The astronomy activities and educational games implemented in this study enabled students to actively participate mentally and physically in the lesson. This situation coincides with the objectives of science programs, which are based on the active participation of students. Especially young children cannot be expected to remain inactive and passive for a long time, so teachers can turn educational games with active participation into learning opportunities (Yörükoğlu, 1993). Teachers may see games only as activities to pass the time or for entertainment (Silvers, 1982). However, considering that students learn better in environments where they feel more comfortable, it should be recommended that games be included more in science teaching. The method of science teaching enriched with activities and games used for the study is based on teachers' effective implementation of activities without much change in the curriculum. It was pointed out that in order to use such activities and educational games effectively, they should be easy to understand and allow active participation, and teachers should be able to keep the game under control throughout the lesson (Şaşmaz & Erduran, 2004). It was also emphasized that the teacher should prepare the activities and games in advance and be a good environmental organizer (Ergül & Doğan, 2022; Koçyiğit, Tuğluk, & Kök, 2007). In addition, students can generate new ideas during the games and perform at a higher level than expected (Seo, 2003).

Science is a subject that contains many abstract concepts. Astronomy, which is included in science, continues to add new concepts to its already abundant knowledge with developing technology. Astronomy lessons, which already contain many abstract concepts, can sometimes become boring for younger age groups. It is believed that more effective results can be obtained in these lessons when taught with activities and games.

7. Implications

Astronomy concepts are quite abstract, and learning cannot be retained, especially for young age groups. In this study, games and activities developed online and as materials revealed that students comprehended abstract concepts better, both cognitively and effectively. In the following process, mobile game designs can be created by considering affective dimensions, and these game elements can be used effectively. Educational game design takes time; especially in mobile games, it can be predicted that getting help from an expert will increase the quality of the games. Training programs can be arranged for teachers to enhance their skills in creating mobile games or designing educational activities. Providing a book or online environment for the prepared educational games or mobile games will be useful for teachers and students. In the study, more comprehensive educational games and activities that can narrow the scope of the unit, including astronomy topics, will be prepared. Almost all of the concepts in science teaching are suitable for online game design. Therefore, mobile, online, or three-dimensional game designs specific to each subject can be developed in the future.

8. Limitations

This study is limited to students attending secondary school in a province in Turkey. The study focuses on the acquisitions of the 6th grade 'Solar System and Eclipses' unit. The educational games and activities in the study will be restricted to those prepared by the researchers. There are many units and learning outcomes in the science curriculum. Numerous activities and educational games can be designed and developed to achieve these outcomes.

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