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Enhancing academic achievement and retention of sixth-grade students through the implementation of educational games in teaching algebraic expressions*[1]

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Abstract

This study aims to investigate the impact of incorporating educational games in the instruction of algebraic expressions on the academic achievement and long-term retention of sixth-grade students. The sample of the study consists of 31 sixth-grade students. These students are enrolled in schools located in the central district of Niğde. The research employed a quasi-experimental design with a pre-test – post-test unequalized control group, which is a quantitative research method. The data for the study were collected using the Algebraic Expressions Achievement Test, developed specifically by the researcher. The data analysis was conducted using the SPSS program, and it was found that the collected data followed a normal distribution. Therefore, the t-test was employed to compare the groups based on the sub-problems of the research, while the ANOVA test was utilized to compare the groups. The results of the analysis revealed a significant difference between the two groups, with the experimental group exhibiting higher achievement scores compared to the control group after the implementation of the educational games. Furthermore, during the follow-up test conducted six weeks later, it was observed that the students in the experimental group maintained their level of achievement, whereas the control group experienced a decline in their scores. There was no significant difference between the post-test and the retention test, indicating that the impact of the teaching intervention remained stable over time. In other words, implementing mathematics instruction through educational games was found to enhance students' academic achievement and ensure long-term retention.

Keywords: Educational Game, Mathematics, Algebraic Expressions, Academic Achievement, Persistence

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INTRODUCTION

Mathematics is an integral part of our daily lives, permeating every aspect of our existence. Because everything people do during the day is somehow related to mathematics, we encounter and utilize various mathematical operations and concepts in our activities (Kaçar, 2020). Hence, possessing mathematical knowledge and skills is crucial not only in our personal lives but also in our professional endeavours (Ünlü, 2020). Moreover, there is a pressing need for individuals who possess mathematical knowledge, think critically and analytically, and possess problem-solving abilities in all sectors of society (National Council of Teachers of Mathematics [NCTM], 2020). This highlights the fallacy of perceiving mathematics solely as a subject confined to the classroom, emphasizing the significance of personal development in mathematics and its role in societal progress.

Mathematics education plays a vital role in shaping human behaviour and fostering the development of logical thinking (Göker, 1997). Altun (2014) highlights the significance of the teaching approach when introducing mathematics in the classroom. It is essential to demonstrate the relevance of mathematics in various contexts, build a solid foundation for each concept, use language that students can comprehend, and establish connections between different mathematical topics. Due to its sequential nature, students should acquire prerequisite concepts before progressing to new material. The teacher's role involves explaining and discussing concepts with students, while also monitoring their progress. To encourage student interaction and collaboration, opportunities for group work should be provided. Furthermore, bringing real-world factors into the classroom and relating mathematical concepts to students' surroundings help make mathematics more meaningful and relatable.

Aydın (2018) points out that many students perceive mathematics as a difficult or even impossible subject, and overcoming such preconceived notions can be challenging. Identifying the underlying issues and addressing the core problems is crucial for understanding students' difficulties. In this context, creating environments that actively engage students and foster their willingness to participate becomes essential in mathematics instruction. Encouraging students to internalize knowledge and grasp abstract concepts can be facilitated through enjoyable and interactive experiences. One effective approach is incorporating educational games that students genuinely enjoy within the school setting, as it provides an avenue for learning content that might otherwise seem challenging or abstract.

For some, play is considered as having a pleasant time, laughing, and having fun, while for others it is considered as looking at life from a different perspective, discovering while having fun, and developing intelligence. Although for most adults, play is seen as wasting the time of the child or student without any purpose play is a need like eating and drinking. According to Yavuzer (2019), who defines the game as the focus of education, the game is that the child learns the subjects that he cannot learn with the help of someone else, thanks to his acquisitions, without thinking about the result, thanks to the movements he makes for fun. Varışoğlu et al. (2013) defined educational games as all activities that positively affect the development of the child, allow the child to develop a sense of happiness and pleasure, enable the child to gain good and good behaviours, and make them a habit; Aykaç and Köğce (2021) defined them as a set of activities that lead to the targeted achievement of the lesson in a pleasant way that enables students to participate actively in the learning process physically and spiritually. In other words, including games during the lesson makes the lessons interesting and increases students' motivation towards the lesson (Açıkgöz, 2003). In addition, educational games allow for the repetition of what has been learned and the correction of incorrect learning if there is incorrect learning due to its preparation in line with a specific purpose and plan (Yavuzyılmaz, 2018). Thanks to all these situations, the student will learn by feeling happier and enjoying the process, discovering the information through his own experiences instead of getting it directly from the teacher.

One of the focal points emphasized in the mathematics curriculum (Ministry of National Education [MoNE], 2018), which adopts a constructivist educational approach, is the creation of learning environments where students can explore knowledge, engage in interactions, and share their ideas while seeking solutions to questions and problems. Various teaching methods and techniques can be employed in constructivist classrooms that foster such environments. One such method is active learning, which emphasizes the importance of a student-centered educational setting. Grounded in the constructivist learning theory, active learning involves activities that facilitate the development of students' critical thinking skills, enabling them to access information through their cognitive processes rather than simply receiving direct instruction. These activities actively engage students in the learning process, encouraging them to internalize information while enjoying the learning experience. Educational games utilized within these learning environments fully serve this purpose. These activities play a significant role in helping students discover the enjoyable aspects of mathematics, aligning with the principles outlined in the current mathematics curriculum. Furthermore, they enable students to actively participate, both mentally and physically, in the learning process, facilitating their understanding of mathematical concepts.

Understanding and comprehending algebra, one of the branches of mathematics, poses challenges for students. Therefore, it is crucial to enrich the learning process to facilitate understanding and make sense of the subject. Algebra holds significance not only for advancing mathematics education but also for pursuing higher education and for encountering algebraic concepts in various aspects of life (Ersoy, 1997). Dede and Argün (2003) assert that algebra plays a critical role not only within the realm of mathematics but also in problem-solving across other disciplines and daily life situations. Algebra serves as both a school subject and a tool for problem-solving and critical thinking. In essence, algebra can be seen as the key to achievement in mathematics and other academic fields. MacGregor and Stacey (1997) note that algebra possesses its unique structure and language, featuring distinct rules and a language that differs from everyday usage, thereby contributing to students' difficulties in comprehending the subject. Arık Karamık (2021) emphasizes the importance of utilizing games in algebra instruction, particularly in the context of a constructivist approach. Mathematical games incorporated into mathematics lessons not only foster creative thinking and experimentation but also enable students to engage with the mathematical rules required. They serve as integral components of problem-solving activities and, as student-centred endeavours, allow students to utilize available information, establish connections between existing schemas, develop those connections further, and reinforce existing knowledge through newly formed connections. Algebraic expressions, being among the initial topics where students encounter abstract thinking in their educational journey, can be intimidating due to their symbolic nature. However, if students acquire these concepts through personal experiences, meaningful learning occurs, leading to improved learning outcomes, enhanced self-confidence, and increased aptitude for solving real-life problems with greater ease.

As mentioned above, students have difficulties in learning mathematics outcomes in general and algebra outcomes in particular. To overcome these difficulties, researchers recommend the use of different teaching methods and techniques in which students can actively participate in the process. One of the methods that can make students active in the teaching process is educational games. According to Aykaç and Köğce (2021), educational games are activities that enable students to participate actively in the process physically, mentally, and emotionally, and reach the achievements of the course in an enjoyable and fun way.

The reason for choosing sixth-grade students for the study is that in the curriculum, students encounter the subject of algebraic expressions for the first time. Until the students reach the sixth grade, they are made to use symbols such as square, round, etc. instead of the unknown in an implicit way and to create mathematical sentences. However, using letter expressions for the unknown and using these letters to form equations and equations in algebraic expressions stand out as an acquisition encountered for the first time at the sixth-grade level (Yenilmez & Avcu, 2009).

Based on the aforementioned information, it is hypothesized that teaching algebraic expressions using educational games can effectively enhance students' mathematical achievement and facilitate long-term learning. Therefore, this study aims to investigate the impact of utilizing educational games to teach the algebraic expressions sub-learning domain within the field of algebra on the academic achievement and retention of sixth-grade students. The anticipated findings of this research are expected to provide valuable insights and serve as an exemplar for educators and mathematics teachers seeking to integrate educational games into their instructional practices.

To address the research objective, the following research question has been formulated: "What is the effect of incorporating educational games to teach the algebraic expressions sub-learning domain of the sixth-grade mathematics curriculum on students' academic achievement and the durability of their achievement?" This question will guide the investigation, alongside the main research objective. Additionally, the study will explore the following sub-questions in line with the problem statement and research objective.

i. Are there significant differences between the pre-test scores in mathematics achievement for the experimental group, who receive education supported by educational games, and the control group, who receive education based on the current curriculum?
ii. Are there significant differences between the pre-test, post-test and retention test scores in mathematics achievement for the experimental group, who receive education supported by educational games?
iii. Are there significant differences between the pre-test, post-test and retention test scores in mathematics achievement for the control group, who receive education based on the current curriculum?
iv. Is there a significant difference between the retention test scores in mathematics achievement for the experimental group, who receive education supported by educational games, and the control group, who receive education based on the current curriculum?

METHOD

Research Design

The research employed a quasi-experimental design with a pre-test – post-test unequalized control group, which is a quantitative research method. This design was chosen due to the implementation of educational games for teaching algebraic expressions to sixth-grade students in the experimental group, while the control group received instruction based on the methods outlined in the current curriculum. The inclusion of pre-test and post-test assessments further justifies the selection of this research design. The research process is presented in Table 1.

Table 1. Implementation Process

Group	Pre-test	Experiment Phase	Post-test	After Experiment (6 Weeks)
Experimental Group	Achievement Test	Teaching algebraic expressions using educational games	Achievement Test	Retention Test
Control Group	Achievement Test	Teaching algebraic expressions with the methods in the current curriculum	Achievement Test	Retention Test

Population and Sample

The population of the study consists of sixth-grade students studying in state-affiliated secondary schools in Niğde in the 2022-2023 academic year. The sample of the study consists of the sixth-grade students of two secondary schools with similar physical conditions in the central district of Niğde

province. The reason why the research was conducted with students in two different schools is that there is only one branch in the school where the researcher works. Since the other secondary school has more than one sixth-grade branch, one branch was randomly selected among the branches. Thus, the sixth-grade students in the school where the researcher was working were determined as the experimental group and the sixth-grade students in the other school were determined as the control group. In this study, which was conducted with a total of 31 sixth-grade students, there were 12 students (5 girls, 7 boys) in the experimental group and 19 students (10 girls, 9 boys) in the control group.

Data Collection Tool

The data for this study were collected using a researcher-developed Algebraic Expressions Achievement Test (AEST), consisting of twenty multiple-choice questions.

To construct the achievement test, the researcher first examined the objectives outlined in the current curriculum for the algebraic expressions sub-learning area at the sixth-grade level. These objectives included the ability to write algebraic expressions for verbal situations, calculate the values of algebraic expressions for different variables, and explain the meaning of simple algebraic expressions. Based on these objectives, a pool of 50 questions was created by reviewing the relevant literature.

To ensure the quality of the test items, the opinions of three experts and three elementary mathematics teachers from public schools were sought. Feedback and suggestions from these experts and teachers were considered, resulting in a draft achievement test comprising 36 questions. The draft test was piloted, and a validity and reliability study was conducted. Data obtained from the pilot application were analyzed to determine the item difficulty index and item discrimination index for each test item.

Based on the analysis, items with an item difficulty index between 0.40 and 0.80 and a discrimination index of 0.30 and above were included in the final achievement test. Items that did not meet these criteria were removed, resulting in a final test consisting of 20 items. The statistical information of the 20-item achievement test is presented in the table below.

Table 2. Achievement Test Statistics

Achievement Test Features	**Value**
Number of Questions	20
Average Test Difficulty	0,54
Average Discrimination of the Test	0,51
KR-20 Reliability Coefficient	0,85

In the 20-question achievement test, the distribution of the questions was determined by taking into account the course hours and contents of the acquisitions in the current curriculum, and 10 questions were prepared to belong to the acquisition "Writes an algebraic expression appropriate to a verbally given situation and a verbal situation appropriate to a given algebraic expression", 5 questions to belong to the acquisition "Calculates the value of the algebraic expression for different natural number values that the variable will take" and 5 questions to belong to the acquisition "Explains the meaning of simple algebraic expressions". The achievement test used in the research is given in Appendix 1.

Educational Games Used in the Research

To examine the effect of the educational games prepared by the researcher by taking expert opinion to be used in the research, to complete the overlooked points, if any, to evaluate the games and to prevent the problems that may occur during the implementation by gaining experience about the games by the researcher who is the conductor of the games during the process, a pilot study of the games was conducted before the implementation. This pilot study was conducted with a total of seventh and eighth

graders who had already learnt the sixth-grade algebraic expressions. After the pilot study, necessary arrangements were made in the materials and rules of the educational games to be used in the research, the educational games were finalised and 8 educational games were made ready for use. The information about which acquisition the educational games used in the research belong to, what are the tools and materials of the games, how the games are played, and the visuals of the materials used in the games are given in Appendix 2.

Implementation Process and Data Collection

This study aimed to investigate the effect of mathematics teaching using educational games on students' academic achievement and the retention of that achievement. The topic of algebraic expressions in the sixth-grade curriculum was taught with the assistance of educational games in the experimental group, while the control group received instruction using the methods outlined in the current curriculum. Both groups completed the teaching of three objectives related to algebraic expressions in the mathematics curriculum, which was conducted over 10 lesson hours spanning two weeks.

Before the implementation, a pre-test called the AEST, developed by the researcher, was administered to both the experimental and control groups.

The educational games, which were prepared by the researcher and refined based on a pilot study, were implemented for 10 lesson hours during the mathematics classes in the experimental group, following the specified time frame in the lesson plans. Meanwhile, the control group received mathematics instruction based on the current curriculum during the same period.

Upon completion of the implementation, the AEST was administered as a post-test to both groups. Six weeks after the conclusion of the implementation, the experimental and control group students underwent the AEST again as a retention test, marking the completion of the data collection process.

The data obtained from the tests were coded as "1" if the answer given by the students was correct and "0" if the answer given by the students was incorrect or the question was left unanswered and transferred to the SPSS environment.

Data Analysis

While analyzing the data obtained during the research process, firstly, the item difficulty and item discrimination index of the items in the AEST developed by the researcher was determined. The average difficulty, average discrimination and KR-20 reliability coefficient of the 20-item achievement test, which was finalized according to certain criteria, were calculated. Microsoft Excel 2010 program was used for all these calculations. The SPSS program was used to analyze the quantitative data obtained from the achievement test used as a pre-test, post-test and retention test in the process. First of all, the Shapiro-Wilk test was used to determine whether the obtained data showed normal distribution since the number of students in the groups was less than 50. Since it was seen that parametric tests could be used in the comparisons to be made between or within groups with the result obtained here, it was decided to use an independent sample t-test and one-factor ANOVA test for repeated (related) measurements to analyze the data. Thus, the independent (unrelated) sample t-test was used in cases where the experimental and control groups needed to be compared, and the one-factor ANOVA test for repeated (related) measures was used in the comparison of pre-test, post-test and retention test scores within the groups, and the analysis was completed in the SPSS 27 package program at 95% confidence interval ($p < 0,05$).

FINDINGS

Descriptive Statistical Results of the Tests Used in the Research Process

In the studies carried out, first of all, it is checked whether the scores obtained from a continuous variable show a normal distribution. One of the methods used for this is to look at the values of descriptive statistics such as skewness coefficient (skewness) and arithmetic mean. The basis of the analysis is to ensure that the scores obtained do not deviate from normal. For this purpose, the values of the skewness coefficient are examined and if this value is between -1 and +1, it is interpreted that the scores do not deviate significantly from normal. In addition, another way of determining whether the obtained data are normally distributed is to utilize the tests applied by looking at the size of the groups. If the group size is larger than 50, the Kolmogorov-Smirnov test is used, and if the group size is smaller than 50, the Shapiro-Wilk test is used. If the p-value obtained as a result of the analysis using these tests is greater than 0.05, it is interpreted that the data obtained do not deviate significantly from normal, that is, they are normally distributed. Depending on whether the distribution is normal or not, it is decided which of the parametric or nonparametric tests should be used by the sub-problems of the research (Büyüköztürk, 2021).

In this context, in line with the information above, the Shapiro-Wilk test was used in the normality value calculations since the number of students in the study was less than 50. In the research process, the arithmetic averages ($\bar{X}$), standard deviation (SD), kurtosis and skewness values of the scores obtained from the AEST applied to the experimental and control groups as pre-test, post-test and retention test and the p values obtained from the normality test were calculated and these values are given in Table 3.

Table 3. Descriptive Statistical Results for Experimental and Control Groups

Groups	AEST	$\bar{X}$	SD	Kurtosis	Skewness	Shapiro-Wilk (p)
Experiment (N=12)	Pre-test	8,33	2,708	-,614	-,786	,074
	Post-test	14,67	3,551	-1,472	-,036	,246
	Retention Test	14,17	3,927	-1,031	-,290	,157
Control (N=19)	Pre-test	7,42	2,244	-,375	,693	,120
	Post-test	10,11	4,054	-,965	,368	,178
	Retention Test	9,37	3,933	-,243	,341	,856

*p < 0,05

Based on the statistical information provided in Table 3, the examination of the pre-test, post-test, and retention test scores revealed that the p-values were greater than 0.05. This indicates that the data exhibited a normal distribution. Consequently, the independent sample t-test was used to compare the experimental and control groups, while the single-factor ANOVA test was employed for within-group comparisons, by the sub-problems. The obtained p-values from these tests were analyzed to determine whether significant differences existed between the compared variables.

It is important to note that a p-value less than 0.05 signifies a statistically significant difference; however, it does not provide information regarding the magnitude of the effect. In interpreting the mean score comparisons, another statistic used is the effect size. Cohen's d value is commonly utilized for effect size calculations and allows us to assess the extent to which the compared means differ from each other. The range of the d value is between -∞ and +∞, and regardless of its sign, a value of 0.2 indicates a small effect size, while values of 0.5 and 0.8 indicate medium and large effect sizes, respectively. Additionally, the eta-square correlation coefficient, frequently employed in ANOVA tests to measure the strength of the relationship between variables, is used. A value of 0.01 suggests a low impact power, 0.06 indicates average impact power and values of 0.14 and higher suggest a high impact power (Büyüköztürk, 2021).

Therefore, in cases where the obtained p-values significantly differ, Cohen's d and partial eta-square values were also calculated to determine the effect size of the observed differences and provide more

interpretations that are accurate. The sub-problems were addressed and comments were made accordingly.

Findings Regarding the First Sub-Problem of the Study

The first sub-problem of the study aimed to investigate whether there was a significant difference in the pre-test scores of mathematics achievement between the experimental group, which received game-supported education, and the control group, which received education according to the current curriculum. The data utilized to address this question were obtained from the pre-test scores collected using the AEST for both groups. To compare the pre-test achievement scores, an independent sample t-test was conducted. The analysis results are presented in Table 4.

Table 4. Independent Sample T-Test Analysis Results of Experimental and Control Group Students' AEST Pre-test Scores

Groups	N	$\bar{X}$	SD	df	t	p
Experiment	12	8,33	2,708	29	1,018	,317
Control	19	7,42	2,244			

*p < 0,05

Examination of Table 4 reveals that the mean AEST pre-test score for the experimental group was 8.33, while the mean AEST pre-test score for the control group was 7.42. Since the p-value, which represents the level of significance, was found to be greater than 0.05, it was determined that there was no significant difference in the AEST pre-test scores between the two groups [t(29) = 1.018 and p > 0.05]. Consequently, it can be concluded that the students in both the experimental and control groups had similar levels of achievement before the intervention.

Findings Regarding the Second Sub-Problem of the Study

The second sub-problem of the study aimed to investigate whether there was a significant difference in the mathematics achievement scores (pre-test, post-test and retention test) of the experimental group students who received educational game-supported education. The data used to address this question were obtained from the AEST pre-test, post-test and retention test administered to the experimental group. To compare the achievement scores within the experimental group, a single-factor ANOVA test was conducted. The analysis results are presented in Table 5 and Table 6.

Table 5. Descriptive Statistics of AEST Scores of Experimental Group Students

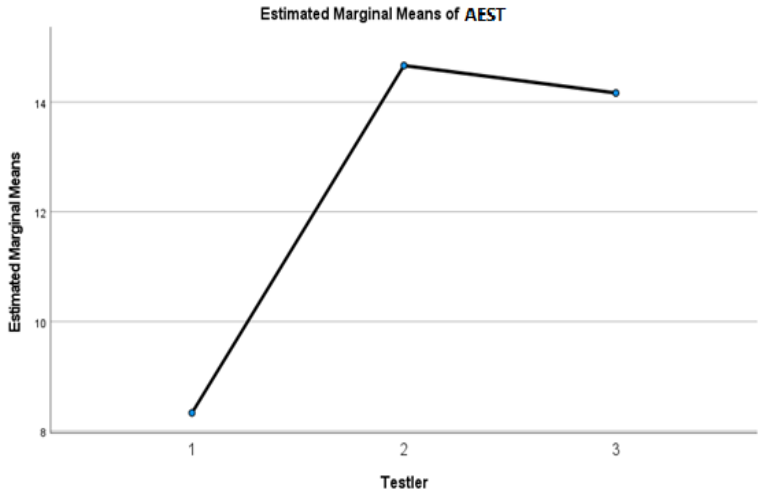
Tests	N	$\bar{X}$	SD
Pre-test	12	8,33	2,708
Post-test	12	14,67	3,551
Retention	12	14,17	3,927

Table 6. One-Factor ANOVA Test Results for Repeated (Related) Measurements of Experimental Group Students' AEST Pre-test, Post-Test and Retention Test Scores

Tests	Sum of Squares	df	Mean Squares	F	p	Significant Difference	Partial eta-squared
Intersubjects	33,519	11	3,047				
Measurement	297,556	2	148,778	11,35	,000	1-2, 1-3	0,51
Error	288,444	22	13,111				
Total	619,519	35					

1: Pre-test, 2: Post-Test, 3: Retention Test

Significant differences were observed among the pre-test, post-test and retention test scores of the experimental group students [F (2, 22) = 11.35, p < 0,05]. The results of the Bonferroni pairwise comparison test indicated that the differences were between the pre-test ($\overline{X}$=8.33) and post-test ($\overline{X}$=14.67) scores, as well as between the pre-test ($\overline{X}$=8.33) and retention test ($\overline{X}$=14.17) scores, favouring the post-test and retention test. The calculated effect size (partial η^2 = 0.51) suggests that 51% of the variability observed in the student's test scores can be attributed to mathematics teaching with educational games. These findings demonstrate a significant increase in test scores for the experimental group students following the application, and the effect of the intervention persisted in the subsequent measurements, as evidenced by the similarity between the post-test and retention test scores. Figure 1 illustrates the changes in scores over time.



*1: Pre-test, 2: Post-Test, 3: Retention Test

Figure 1. Pre-Test, Post-Test and Retention Test of Experimental Group Students Change Graph Between Scores

Figure 1 demonstrates that the retention test achievement scores of the experimental group students remained consistent with the post-test achievement scores. This finding indicates that mathematics teaching with educational games facilitated the retention of students' achievement.

Findings Related to the Third Sub-Problem of the Research

The data to be used to answer the third sub-problem of the study, "Is there a significant difference between the mathematics achievement pre-test, post-test and retention test scores of the control group students who received education according to the current curriculum?" were obtained from the AEST pre-test, post-test and retention test applied to the control group, and the one-factor ANOVA test for repeated (related) measurements was used to compare the achievement scores within the group. The results of the analysis are given in Table 7 and Table 8.

Table 7. Descriptive Statistics of Control Group Students' AEST Scores

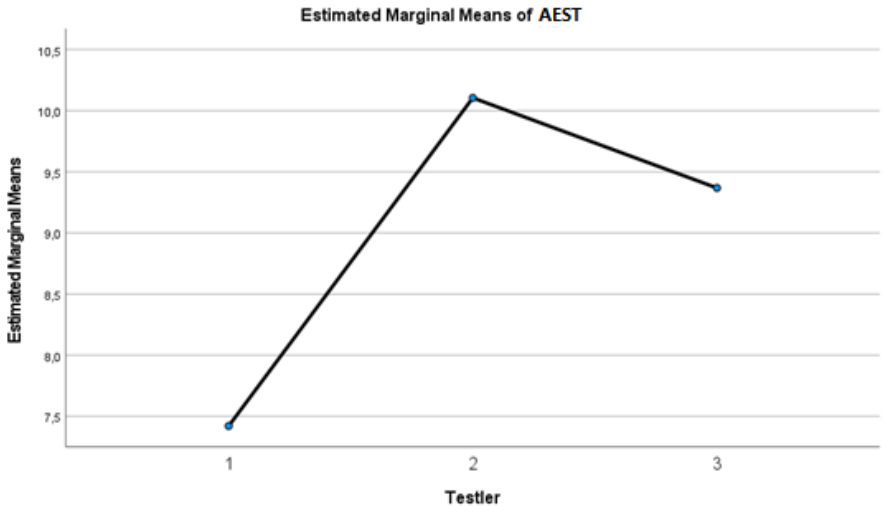
Tests	N	$\overline{X}$	SD
Pre-test	19	7,42	2,244
Post-test	19	10,11	4,054
Retention	19	9,37	3,933

Table 8. One-Factor ANOVA Test Results for Repeated (Related) Measurements of Control Group Students' AEST Pre-test, Post-Test and Retention Test Scores

Tests	Sum of Squares	df	Mean Squares	F	p	Significant Difference	Partial eta-squared
Intersubjects	94,199	18	5,233				
Measurement	73,088	2	36,544	3,44	,043	1-2	0,16
Error	382,246	36	10,618				
Total	549,533	56					

1: Pre-test, 2: Post-Test, 3: Retention Test

There was a significant difference in the pre-test, post-test and retention test scores of the control group students [F (2,36) = 3.44 and p < 0,05]. According to the results of the Bonferroni pairwise comparison test conducted to identify the specific differences between the tests, it was found that the difference was only significant between the pre-test ($\overline{X}$ = 7,42) and post-test ($\overline{X}$ = 10,11) scores, favouring ttheanalyzing the calculated effect size (partial η^2 = 0,16), it can be concluded that 16% of the variation observed in the student's test scores is attributed to teaching mathematics using the current curriculum. These findings indicate that the test scores of the control group students who received education according to the current curriculum increased significantly only in the measurements taken after the implementation. Furthermore, the test scores after the implementation deviated from the retention test scores conducted later, indicating that the effect of the implementation did not persist. The changes between the scores are depicted in Figure 2.



*1: Pre-test, 2: Post-Test, 3: Retention Test

Figure 2. Pre-Test, Post-Test and Retention Test of Control Group Students Change Graph Between Scores

As depicted in Figure 2, it is evident that the retention test achievement scores of the control group students diverged from the post-test achievement scores. Therefore, it can be concluded that the impact of mathematics teaching based on the current curriculum on students' achievement diminished over time.

Findings Related to the Fourth Sub-Problem of the Research

The data collected for addressing the fourth problem of the study, which investigates the potential difference in mathematics achievement retention test scores between the experimental group students who received educational game-supported education and the control group students who received

education according to the current curriculum, were gathered through the administration of the AEST retention test to both groups. The independent sample t-test was employed to compare the retention test achievement scores. The analysis results can be found in Table 9.

Table 9. Independent Sample T-Test Analysis Results of the AEST Retention Test Scores of Experimental and Control Group Students

Groups	N	$\bar{X}$	SD	df	t	p	Cohen-d
Experiment	12	14,17	3,927	29	3,310	,002	1,221
Control	19	9,37	3,933				

*p < 0,05

Upon examining Table 9, it is evident that the mean AEST retention test score for the experimental group was 14.17, whereas the mean AEST retention test score for the control group was 9.37. The obtained p-value, which is less than 0.05, indicates a significant difference in the AEST retention test scores between the two groups [t (29) = 3.310 and p < 0,05]. Given the significant result, the effect size, as measured by the Cohen-d value, was calculated to be 1.221. These findings collectively suggest that the difference in AEST retention test scores between the experimental and control group students had a substantial effect in favour of the experimental group, reaching a large effect size (d > 0.8). Consequently, it can be concluded that mathematics teaching incorporating educational games has a significant and positive impact on the retention of students' achievement levels.

DISCUSSION, CONCLUSION AND SUGGESTIONS

Firstly, the analysis examined whether there were any differences in the pre-test scores between the students in the experimental and control groups. The results indicated that the mean achievement of the experimental group students did not significantly differ from that of the control group students. This finding suggests that both groups had similar academic achievement levels before the implementation of the study.

Regarding the second sub-problem, the comparison of pre-test, post-test, and retention test scores of the experimental group students yielded significant differences. The analysis revealed that significant differences were observed between the pre-test and post-test scores, as well as between the pre-test and retention test scores. Additionally, it was observed that the post-test and retention test scores of the experimental group students were relatively close to each other and did not show significant divergence. These results demonstrate that mathematics teaching utilizing educational games has a positive impact on enhancing students' academic achievement and facilitating the retention of acquired knowledge throughout the learning process.

Based on the findings related to the third sub-problem of the study, a significant difference was observed when comparing the pre-test, post-test and retention test scores of the control group students. The analysis indicated that a significant difference existed only between the pre-test and post-test scores. Furthermore, upon analyzing the results, it was observed that the post-test and retention test scores of the control group students diverged from each other. These results indicate that mathematics teaching according to the current curriculum is effective in enhancing students' academic achievement. However, it does not ensure the long-term retention of the acquired knowledge.

Finally, the analysis examined whether there were any differences in the retention test scores between the students in the experimental and control groups. The results revealed a significant difference in the mean achievement of the experimental group students compared to the control group students, favouring the experimental group. Additionally, the effect size was found to be substantial. These results demonstrate that mathematics teaching utilizing educational games has a significant impact on the

retention of knowledge acquired by students compared to mathematics teaching according to the current curriculum.

The results obtained from this study are in parallel with the results of studies on different subjects with different sample groups. Başün and Doğan (2020) examined the effect of teaching with games on student achievement and retention of achievement in the sub-learning area of multipliers and multiples in the sixth-grade mathematics course and found a significant difference in favour of the experimental group in the achievement and retention of the achievement of the experimental and control group students. In his study, Demir (2016) aimed to determine the effect of mathematics teaching using different types of games on the achievement and retention level of first-grade students. As a result of the study, it was determined that there was a significant difference in favour of the experimental group between the students' mathematics course academic achievement test achievement averages and retention averages. The study conducted by Gün, Işık and Şahin (2021), it was investigated how the use of the game called "Apartment Sudoku" in the education process affects the academic achievement of tenth-grade students in some acquisitions belonging to the sub-learning areas of counting and probability. In the light of the findings obtained as a result of the study, it was seen that the game teaching method was statistically significantly effective and according to the results of the retention test conducted at the end of the application, it was seen that the game teaching method created significant permanent learning. Again, it is seen that the results obtained from studies conducted in different disciplines are in harmony with the results of this study. Erol, Erdem and Akkaya (2021) conducted a study to determine the effect of using educational games in teaching Turkish as a foreign language on students' achievement and retention of what is learnt, and as a result of the research, they concluded that the use of educational games increased student achievement and provided permanent learning. Gedik (2017) aimed to reveal the effect of using educational games in the development of seventh-grade students' reading skills on achievement and retention, and as a result, it was determined that the teaching technique with educational games was more effective in developing students' reading skills than the current curriculum approaches. The study conducted by Karabağ and Aydoğan (2015), it was aimed to determine the effect of using the game method in history lessons on student achievement and retention of learning, and as a result of the study, it was determined that the achievement and retention levels of the experimental group students, in which history teaching was carried out with the game method, were higher. Yıldız and Şimşek (2020), on the other hand, concluded that the use of educational games increased student achievement and retention of knowledge in their study conducted to examine the effect of using educational games in science courses on students' academic achievement and retention of knowledge. Similarly, in the studies conducted by Alıcı (2016); Atay (2018); Gürbüz, Çeker and Töman (2017); Torun and Duran (2014); Yıldırım (2015), it was found that educational games increased the achievement of students and provided the retention of learned information, and these results are in line with the results of this study. Based on these consistent results, the following suggestions are provided to offer insights for future researchers who will investigate this subject matter.

This study focused on the sixth-grade algebraic expressions subject, demonstrating the significant benefits of educational games in enhancing student achievement and promoting knowledge retention. Therefore, it is recommended to investigate the impact of educational games on mathematics achievement and retention in other subjects within the mathematics curriculum and across different grade levels. In this study, mathematics teaching using educational games was compared to traditional teaching methods outlined in the current curriculum. Future research can explore the comparison of educational games with alternative teaching approaches, allowing for a comprehensive analysis of their effects on the learning process. Due to the researcher's affiliation with a small village school, this study involved a sample of only 12 students. A larger-scale study with a higher number of students in the experimental group can re-examine the effects of educational games, utilizing the same games employed in this study. The educational games used in this study were developed by the researcher. In future investigations on the impact of educational games, researchers can involve students in the game

development process, taking into account their input and requests. The educational games employed in this study were in tangible, concrete form. To broaden the scope of research, digital games can be developed and studied on the same subject, allowing for an examination of their effects on student achievement and retention. To facilitate the regular integration of educational games in classroom instruction, it is recommended to establish a platform where teachers can share the educational games they have created with one another.

Statement of Researchers

Researchers' contribution rate statement: Researchers contributed equally to this study.
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APPENDIX-1 Algebraic Expressions Achievement Test

Algebraic Expressions Achievement Test

1. "Ahmet'in cebindeki paranın 3 katının 10 eksiği" ifadesinin cebirsel ifade karşılığı aşağıdakilerden hangisidir?

A) $x - 10.3$
B) $10x - 3$
C) $3x - 10$
D) $3.(x - 10)$

2. "Okulumuzda bulunan sınıf sayısının 5 fazlasının yarısı" ifadesine ait cebirsel ifade aşağıdakilerden hangisidir?

A) $x + \frac{5}{2}$
B) $\frac{x+5}{2}$
C) $\frac{x}{2} + 5$
D) $x + 5$

3. İpek'in a tane oyuncağı vardır. Ablası Nehir'in oyuncak sayısı ise İpek'in oyuncak sayısının 3 katından 7 eksiktir. Buna göre Nehir'in oyuncak sayısını gösteren cebirsel ifade aşağıdakilerden hangisidir?

A) $7 - 3a$
B) $7.(a - 3)$
C) $3.(a - 7)$
D) $3a - 7$

4. Aşağıdaki ifadelerden hangisi $4x + 5$ cebirsel ifadesine karşılık gelir?

A) Bir ahırdaki inek sayısının 4 katının 5 fazlası
B) Evdeki sandalye sayısının 5 katının 4 fazlası
C) Bir bahçedeki papatyaların 5 fazlasının 4 katı
D) Okuldaki öğretmen sayısının 4 fazlasının 5 katı

5. Aşağıdakilerden hangisi cebirsel ifade değildir?

A) $5.s$
B) $r + 3$
C) $4\mathrm{a} - 5\mathrm{n} + 8$
D) $92 - 80$

6. $3a + 4b + 5c - 11$

Yukarıda verilen cebirsel ifade için aşağıdakilerden hangisi yanlıştır?

A) Dört terimden oluşmaktadır.
B) Katsayılar toplamı 1'dir.
C) Üç değişkeni vardır.
D) Sabit terimi 11'dir

7.

- 2 farklı değişkeni vardır.
- Sabit terimi 1'dir.
- Katsayılar toplamı 6'dır.
- Terim sayısı 3'tür.

İfadelerine uygun olan cebirsel ifade aşağıdakilerden hangisidir?

A) $5x + 1$
B) $2a + 4b + 1$
C) $3p + 2r + 1$

D) $2m + 2n + s + 1$

8. Aşağıdakilerden hangisinde verilen cebirsel ifadeler benzer terimler değildir?

A) $3x \; ile \; \frac{x}{5}$ C) $9a \; ile - 3a$

B) $5b \; ile \; 8$ D) $2mn \; ile \; 3mn$

9. Aşağıdaki cebirsel ifadelerden hangisinde değişkenlerin katsayılar toplamı sabit terime eşittir?

A) $x + 2y + 1$

B) $2x + 3y + z + 5$

C) $4x + 3y - 3z + 4$

D) $5x + 2y + 2z + 7$

10.

I	Ömer 'in yaşının 4 fazlası
II	Bir sayının yarısının 2 eksiği
III	Gidilecek bir yolun 3'te birinin 4 fazlası
IV	Bir miktar parayı 4 kişi eşit paylaştığında bir kişiye düşen para

Tablo - I

L	$\frac{a}{2} - 2$
O	$n + 4$
K	$\frac{y}{4}$
U	$\frac{k}{3} + 4$

Tablo - II

Yukarıda Tablo-1'de verilen sözel ifadeler, Tablo-2'de verilen uygun cebirsel ifadelerle sırasıyla eşleştirildiğinde oluşan şifre aşağıdakilerden hangisidir?

A) O L U K B) K O L U

C) O K U L D) U L O K

11. $a = 2$ için $39 - 2a$ cebirsel ifadesinin değeri kaçtır?

A) 35 B) 29 C) 23 D) 17

12. Aşağıdaki cebirsel ifadelerin hangisinde x'in değeri için işlemin sonucu yanlış bulunmuştur?

A) $x = 1$ için "$2.(x + 5)$"in değeri 12'dir.

B) $x = 2$ için "$x^2 - 1$"in değeri 3'tür.

C) $x = 5$ için "$4x + 3$"ün değeri 23'tür.

D) $x = 4$ için "$2x + 5$"in değeri 29'dur.

13. $n = 4$ için aşağıdaki cebirsel ifadelerden hangisinin değeri diğerlerinden farklı olur?

A) $n^2 + 2$ B) $5.n - 2$

C) $n + 10$ D) $6.(n - 1)$

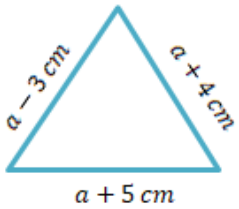
14. $7x - y$ cebirsel ifadesinin x ve y değişkenlerine verilen hangi değerler için sonuç yanlış hesaplanmıştır?

	x	y	Sonuç
A)	1	1	6
B)	1	2	5

C) 2 1 15

D) 2 2 12

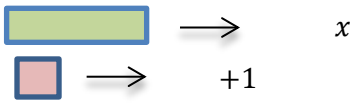
15.



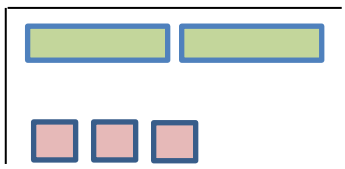
Yukarıda kenar uzunlukları verilen üçgenin çevre uzunluğu $a = 5$ için kaç cm olur?

A) 20 B) 21 C) 22 D) 23

16.



Yukarıda verilen ifadelere göre aşağıdaki modellemeye karşılık gelen cebirsel ifade aşağıdakilerden hangisidir?



A) $3x + 2$ B) $2x + 3$

C) $3x - 2$ D) $2x - 3$

17. ★ → x ve ● → -1 olarak modellenmiştir. Buna göre $2x - 5$ cebirsel ifadesi aşağıdakilerden hangisinde doğru modellenmiştir?

A) ★★●●●

B) ★●●●●●

C) ★★★★★●●

D) ★★●●●●

18. Bir basketbol turnuvasında a tane 3 sayılık, b tane 2 sayılık ve 4 tane 1 sayılık basket atan Yaman'ın turnuva sonunda takımına kazandırdığı toplam sayı aşağıdaki cebirsel ifadelerden hangisidir?

A) $3a + 2b$

B) $3.(3a + 4)$

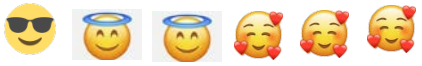
C) $2.(2b + 4)$

D) $3a + 2b + 4$

19. Aşağıda verilen emojiler yanlarında yazan harfler ve sayı ile tanımlanmıştır.

😎 → x , 😇 → y 🥰 → $+1$

Eliz telefonunda bulunan bir uygulama ile arkadaşına aşağıdaki emojileri göndermiştir.



A) $x + 2y$ B) $x + 2y + 3$

C) $2x + y + 3$ D) $x + y + 1$

20. Nuran Hanım gittiği marketten kilogramı fiyatı m lira olan elmalardan 5 kg ve kilogram fiyatı n lira olan üzümlerden 3 kg almıştır. Buna göre Nuran Hanım'ın aldığı meyveler için markete ödediği toplam parayı lira cinsinden gösteren cebirsel ifade aşağıdakilerden hangisidir?

A) $m + n$

B) $5m + 3n$

C) $m - n$

D) $3m + 5n$

APPENDIX-2 Educational Games Used in the Study

1- Educational Game Called "Let's Construct Algebraic Expressions"

Acquisition: Writes an algebraic expression appropriate to a verbally given situation and a verbal situation appropriate to a given algebraic expression**.**

Tools and Materials: In a box, papers with verbal expressions on them, each of which is of equal size, letter cards to represent variables, number cards from 1 to 10 and symbols cards representing addition, subtraction, division operations and parenthesis images.

How to play? : Students form groups of two. Each group determines a name for itself. The group names are written on the board. The teacher gives each group cards with letters and numbers representing variables and symbols for addition, subtraction and division. Symbols are not given for multiplication because the students are made to discover that the multiplication operation stated in the expression "2 times a number" is multiplication even if no symbol is placed between the coefficient 2 and the letter representing the variable. After the distribution process is completed, the box on the table is shown to the students. It is said that there are verbal expressions on the papers in the box, and after the teacher reads these expressions, each group should form the algebraic expression of the verbal expression with the materials in their hands. The first group that forms the algebraic expression belonging to the verbal expression correctly and completely receives 10 points, then each group that completes the algebraic expression correctly receives points by decreasing by two as 8, 6, 4, 2, and the last group is given 1 point if it gives the correct answer. Groups are given two minutes to form verbal expressions to manage time more efficiently. If no group can reach the correct answer at the end of the two minutes, this round is passed without points. The game is played in this way and the group that reaches 100 points first wins the game. The winning group is applauded.

Materials for the game called Let's Construct Algebraic Expressions

2- Evaluation Game Called "Find Your Mate"

Acquisition: Writes an algebraic expression appropriate to a verbally given situation and a verbal situation appropriate to a given algebraic expression.

Tools and Materials: Papers containing verbal and algebraic expressions are prepared to be equal to each other.

How to play? : The teacher writes the names of everyone involved in the game on the board. The teacher puts the verbal expressions in the box and the algebraic expressions of these verbal expressions on the floor randomly. The teacher turns on the music and the students dance to the music without stepping on the papers. When the music is switched off, the students take one of the papers on the floor. The students put the expressions on the paper on their chests so that everyone could see them. The students find the friend who has a matching expression on his chest and says "I found my partner". After all matches are completed, starting with the first student who finds his partner correctly, points are given under the name on the board starting from 10 and decreasing to 8, 6, 4, 2, and 1, respectively. One point is removed from the students who made a wrong match. After each match is completed, the teacher distributes other verbal expression and algebraic expression papers from the box. The game is played in this way for 30 minutes. At the end of the time, the points written on the board are calculated for each student and the winner is determined.

Materials for the game called Find Your Mate

3- Educational Game Called "Algebra Says"

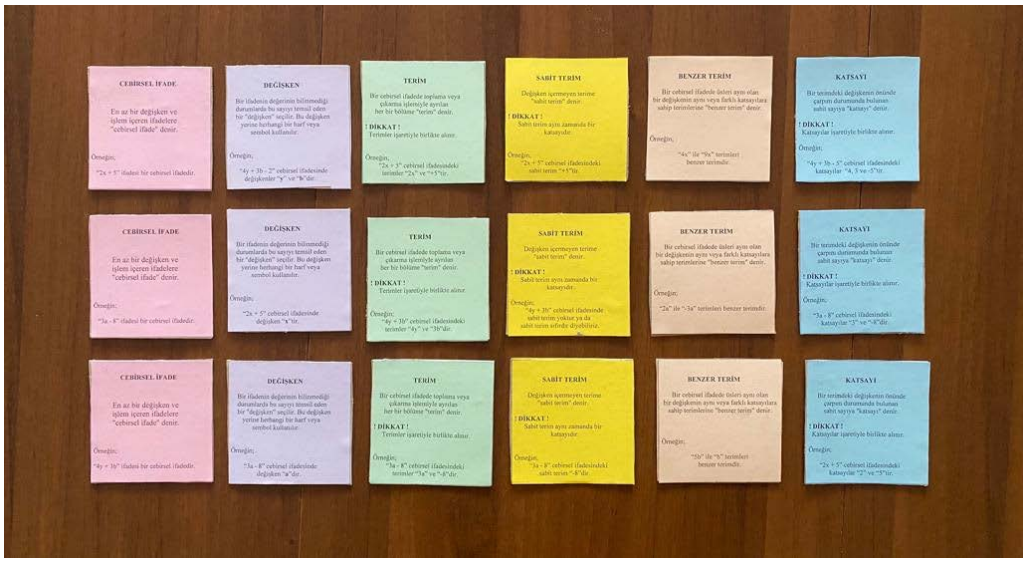
Acquisition: Writes an algebraic expression appropriate to a verbally given situation and a verbal situation appropriate to a given algebraic expression.

Tools and Materials: Information cards prepared enough for each student

How to play? : Students form a circle. The information cards prepared on the subject are randomly distributed to the students. The teacher says that he is in the class today for algebra and that there is information to be learned about this subject. Therefore, he says that he will give commands starting with "algebra says". Sometimes he says that he will give instructions without starting with "algebra says". He says that these instructions should not be followed. If anyone does not follow the instructions or is confused, he reads the flashcard aloud to the class twice and gives the instructions together with the teacher after the reading process is over. Some sample instructions are given below.

- Algebra says that everyone should jump.
- Algebra says clap for each other.
- Everyone sits down.
- Everyone dances.
- Algebra says everyone raises their right hand in the air.
- Everybody hold your nose.
- Algebra says everyone put your hand on the shoulder of the friend to your right.
- Everyone turns round.
- Algebra says nobody moves.
- Everyone stands on one leg.
- Algebra says everybody shut up.
- Everyone covers their mouths with their hands.

The game is continued until the concepts related to the subject are completely learned.



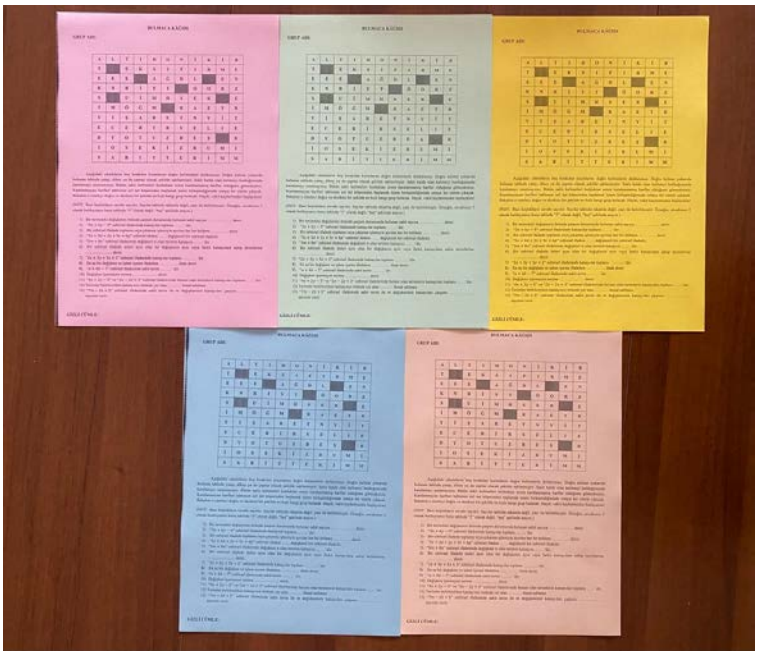
Materials for the game called Algebra Says

4- Evaluation Game Called "Find the Letters, Reveal the Hidden Sentence"

Acquisition: Writes an algebraic expression appropriate to a verbally given situation and a verbal situation appropriate to a given algebraic expression.

Tools and Materials: Pencil and puzzle paper

How to play? : The students form groups of 3 and choose a group name for themselves. The teacher distributes a puzzle sheet to each group and the students write their group names on the puzzle sheet. The group members fill in the blanks at the bottom of the puzzle sheet with the correct words. They find the words in the blanks among the letters hidden horizontally, vertically or diagonally in the table on the upper part of the puzzle sheet and scribble the letters that form the correct word. After all the questions are finished and the scribbling process is completed, the hidden sentence formed by combining the remaining letters is found and this sentence is written in the relevant section of the puzzle sheet. After all groups find the secret sentence, the priority order of the groups is determined according to the time it takes to finish the game. Then each group checks the answers given by another group. The group that does not make mistakes or makes fewer mistakes wins the game. In the case of equality, the group that completes the puzzle before wins the game.



Material for the game called Find the Letters, Reveal the Hidden Sentence

5- Educational Game Called "Spin the Wheels, Find the Value"

Acquisition: Calculates the value of the algebraic expression for different natural number values of the variable.

Tools and Materials: Wheel on which algebraic expressions are written, wheel on which the values of the variable are written, paper, pencil

How to play? : Students become a circle. To determine who will spin the wheels in the game, the teacher throws the folded papers prepared in advance into the air. The student who draws the paper with the visual on it is entitled to spin the wheel. The student spins both the algebraic expression wheel and the value wheel. The student tells the algebraic expression indicated by the arrows and the value of the variable in the algebraic expression aloud to his friends and tries to find the result himself. While finding the result, the student also makes use of the verbal expressions written for each algebraic expression on the algebraic expression wheel. Other students also try to find the results to check the answers of their friends who spin the wheel. The teacher writes the time it takes for the student to find the correct answer on the board. After the result is found, the students become a circle again and the game continues in this way. The game ends when everyone has the right to spin the wheel at least once and the student who reaches the correct answer in the shortest time wins the game.

Material for the game called Spin the Wheels, Find the Value

6- Evaluation Game Called "Value Hidden in Boxes"

Acquisition: Calculates the value of the algebraic expression for different natural number values of the variable.

Tools and Materials: Two boxes, papers on which algebraic expressions are written, papers on which numbers from 1 to 10 (including 10) are written, paper, pencil

How to play? : Students are divided into 2 groups and choose a group name. Group names are written on the board. Group members line up around the table. With the instruction of the teacher, the students

in the front of the groups come to the table and one student draws a paper from the box on the table with the algebraic expression and the other student draws a paper from the box with the numbers. The students read the paper from the box aloud for everyone to hear. Then, the students who draw the papers from the box find the result by accepting the value of the algebraic expression from the box and the number from the other box as the value that the variable will take. If the group members give the correct answer, 1 point is awarded to both groups, and 1 point is awarded to the group that has already reached the correct answer. If there is no correct answer within 2 minutes, both groups are left without points. When the students who played the game return to their groups, they go to the back row and the students at the front of the group come to the table and draw papers from the boxes. The game continues in this way until the end of the lesson. At the end of the lesson, the group with the most points wins the game.

Material for the game called Value Hidden in Boxes

7- Educational Game Called "Let's Unite, Let's Learn the Meaning"

Acquisition: Explains the meaning of simple algebraic expressions.

Tools and Materials: Variable cards and constant term cards that students will hang around their necks, folded papers for draws and 2 + symbols

How to play? : Students are divided into 2 groups and choose a group name. Group names are written on the board. The teacher distributes the cards with x and y variables and +1 constant terms written separately to both groups for the students to hang around their necks. After the students wear the terms around their necks, the teacher throws the folded papers into the air separately for each group. In this way, while the students of one group form the terms, a student from the other group becomes the person who will say the algebraic expression formed. The three students who write "term" on the opened paper stand in front of the other group. The teacher puts the + symbol in both hands between the terms written on the students' necks. Thus, an image of addition is formed between the terms. The student from the other group who draws the writing "algebraic expression" on the opened paper says the algebraic expression formed by the terms directly opposite the group. If the student is correct, he earns 2 points for his group. After the students take their seats, the teacher throws the folded papers into the air, this time in the opposite way, so that the group that formed the terms in the previous game is the group that will say the algebraic expression this time, and the group that says the algebraic expression

is the group that formed the terms. However, for each student to be able to say the algebraic expression at least once, the student who says the algebraic expression is not included in the draw once again, but only that student can be the term. The game continues in this way for a certain period. Then the teacher says that they will change the neck cards and this time the cards with the constant term +1 are removed from the game and the cards with the constant term -1 are included in the game. The neck cards are again randomly distributed to the groups and the game is continued in the same way. The game continues in this way until each student takes a role to say the algebraic expression formed at least once. At the end of the lesson, the group with the most points wins the game.

Material for the game called Let's Unite, Let's Learn the Meaning

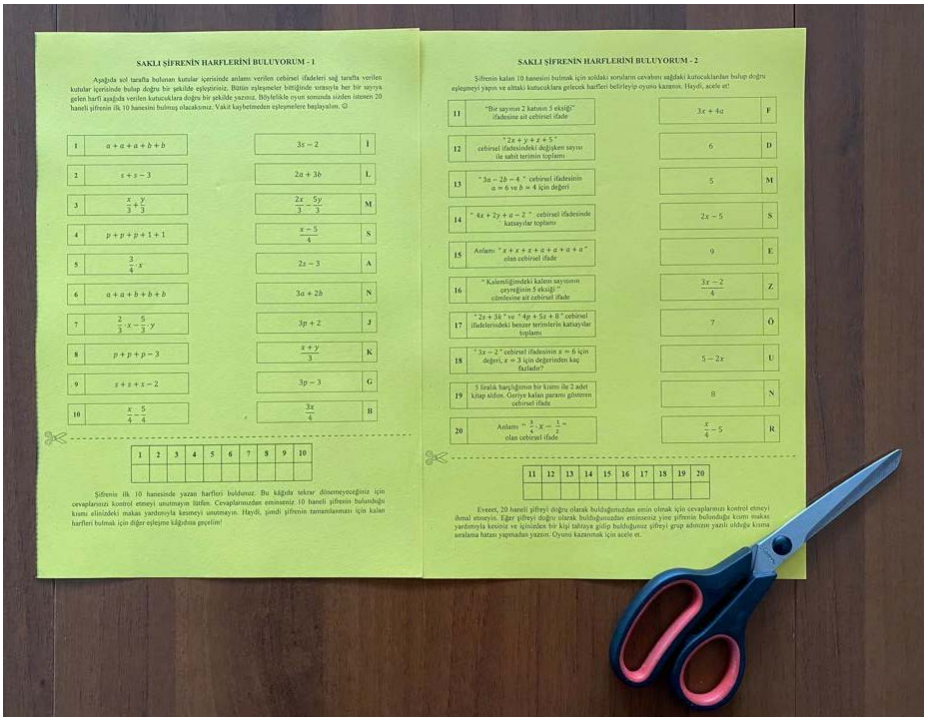
8- Evaluation Game Called "Step by Step I Apply What I Have Learnt"

Acquisition: Explains the meaning of simple algebraic expressions.

Tools and Materials: 2 pieces of matching paper prepared differently from each other, pencil, scissors

How to play? : Students form groups of 3 and each group determines a group name. The class board is divided into equal sections and the group names are written on each section. Since there are two parts in the game, the classroom is organised in such a way that the number of rows of the group is on the wall side and the number of rows of the group is at the level of the board. The teacher puts matching papers prepared separately for the two parts of the game on the desks of each group. The first one of these matching papers contains questions prepared for the evaluation of the relevant outcome, while the second one contains questions evaluating all the outcomes of the algebraic expressions topic. The students first find the first 10 digits of the 20-letter password that will emerge as a result of the matching by following the instructions on the first matching sheet placed on the desks by the wall and the part where the password is written is cut by the group members with the help of scissors. The students now stand in front of the board and make the necessary matches on the paper by answering the questions on the 2nd matching sheet. After the matches are completed, the remaining 10-digit password is found and the necessary part of the paper is cut with the help of scissors. One of the group members goes to the board and writes the 20-digit password he found in the section of his group name. The game ends when all groups write the password on the board. The teacher gives extra points to the groups by decreasing 1 point in the form of 5, 4, 3, 2, 1, starting with the group that finds the password the fastest. The groups change places among themselves and check the correctness of the letters found by each other. For this, the teacher starts to read the next letter in each digit respectively. The groups gain 5 points for each correct letter and lose 3 points for each incorrect letter. After the necessary calculations

are made, the group with the highest score wins the game. In the case of equality of points, the group that completes the password faster wins the game.



Material for the game called Step by Step I Apply What I Have Learnt