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Effect of Authentic Learning Activities in Mathematic Courses on Middle School Students' Academic Achievement and Reasoning Skills

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ABSTRACT
The aim of this study was to determine the effect of activities based on the authentic learning approach used in middle school mathematics courses on students' academic achievement and reasoning skills. The research covers the learning outcomes of the Whole Numbers, Fractions, and Decimal Fractions units in the sixth grade first semester of the mathematics course. The research was implemented in the first semester of the 2022-2023 academic year in a public school in the Selçuklu district of Konya province. The control and experimental groups consisted of 33 and 26 sixth-grade students, respectively. The study was conducted for nine weeks during the fall semester. The data of the study were collected with "Academic Achievement Test" and "Reasoning Skills Test". T-test statistics were used to analyze the data. Because of the study, it was observed that authentic learning activities used in mathematics lessons positively affected students' academic achievement and reasoning skills. These results show that learning experiences close to daily life skills also contribute to reasoning skills.

Keywords: Authentic learning, reasoning skills, mathematics

Introduction

Mathematics is a subject that is often remembered by students because of the difficulties they experienced in school. However, it is not only a part of the school curriculum but also has relevance in every aspect of our daily lives (Hacısalihoğlu et al., 2004). Mathematics has been used to solve many problems that people face directly or indirectly since ancient times, and its relations with different contexts are constantly being redefined (Demir et al., 2023). Mathematics is an important cornerstone in the development of societies. It has been used to determine the boundaries of the lost lands of ancient Egyptians who were engaged in agriculture by the Nile River (Uğuz, 2022). Today, it is used in the development of fields such as artificial intelligence and technology. The significance of teaching mathematics leads to an increased emphasis on its acquisition, which can cause fear and anxiety in many students (Tobias & Weissbrod, 1980). However, several studies have observed a correlation between anxiety and low achievement (Chang & Beilock, 2016; Dowker, Sarkar, & Looi, 2016; Suarez-Pellicioni, Nunez-Pena, & Colome, 2015). Researchers feel compelled to experiment with different designs or approaches to teaching mathematics because of anxiety and fear.

Freudenthal (1971) argues that mathematics is not a closed system to be learned, but rather a discipline in which the learner is active. According to this view, mathematics is a human activity that begins with real-life problems, and formal mathematics is reached only after the mathematization of real-life situations. Today, this teaching approach, based on the constructivist perspective, is known as realistic mathematics education (Van den Heuvel-Panhuizen, 2003). Connecting mathematics with real-life situations aligns with the notion that learning contexts impact both concept formation and development (Vygotsky, 1986). Authentic learning, or real-life-like contexts, is crucial as it provides concrete situations for acquiring everyday concepts. This learning approach facilitates effective learning in various courses, particularly mathematics, which is often viewed as the most abstract.

Authentic Learning

Authentic learning refers to an instructional approach that situates learning experiences in real-world contexts and activities. It is grounded in the constructivist theory, which posits that learning occurs most effectively when learners are actively engaged in building knowledge and making meaning from experiences that resemble real-life scenarios. Authentic learning involves the use of authentic tasks, resources, and environments that are directly relevant to learners' lives and goals. By presenting learners with genuine problems and challenges that mirror those encountered in professional settings, authentic learning bridges the gap between theoretical knowledge and practical application (Newmann, et al., 1992; Lombardi, 2007).

Learners assume roles akin to the work they may undertake in the future, fostering the development of relevant skills, strategies, and dispositions. They engage in complex activities such as case studies, projects, or simulations that require research, collaboration, and critical thinking skills to navigate ambiguous situations that lack a prescribed solution path (Wiggins, 1990; Newmann, & Wehlage, 1993). Authentic assessments are an integral part of this approach, measuring learners' ability to effectively use acquired knowledge rather than merely recalling information.

The authenticity inherent in these learning experiences enhances motivation and engagement as learners find relevance and purpose in their endeavors. It facilitates the transfer of knowledge to novel situations beyond the classroom setting by enabling learners to practice applying concepts in realistic contexts (Renzulli et al, 2004; Herrington, & Herrington, 2006). Ultimately, authentic learning equips learners with the capacity to successfully confront complex real-world challenges by developing essential skills like problem-solving, decision-making, self-directed learning, and adaptability to dynamic environments.

Authentic Learning in Mathematics

Authentic learning involves working on real-world problems and actively participating in the solution (Lam, 2013). The authentic learning model is a process that leads to true mastery through experiences

(Nordquist, 1993). This teaching model focuses on complex problems and includes role-playing, simulations, and real-world applications. Authentic learning involves students finding knowledge in real contexts, using multiple methods to access it, and applying it to gain experience (Newman et al., 1995). This process equips students with skills that extend beyond memorization and are applicable throughout their lives (Lombardi, 2007). It also challenges them with complex problem-solving tasks. In this process, students encounter decision-making situations similar to those in their daily lives (Lombardi, 2007). Authentic tasks require individuals to make decisions using a variety of knowledge and skills (Perreault, 1999). Therefore, authentic learning offers an important experience for students to develop decision-making skills, which are necessary in the 21st century. Many students perceive mathematics as a subject that requires rote memorisation, without understanding its practical applications. They often view it as a collection of formulas (Tobias & Weissbrod, 1980). To address this, an authentic learning strategy can be employed, which connects mathematical concepts to real-life situations, demonstrating that abstract knowledge has tangible applications in daily life. Therefore, the use of authentic learning strategies facilitates the mental organization of information and enhances the enjoyment of the learning process (Aydın-Aşk, 2016). This approach not only promotes students' interests in the subject matter but also emphasizes that the lesson is not solely based on rote memorization. Consequently, individuals who structure their knowledge rather than relying on memorization tend to retain information more effectively (Koçyiğit & Zembat, 2013). It is evident that a learning environment where students have the opportunity to work and experiment independently can enhance their academic performance and mathematical reasoning abilities, as well as foster their development as mathematicians.

Authentic Learning and Mathematical Reasoning

Various studies have focused on the mathematical thinking processes of students (Tüzün & Cihangir, 2020). Specifically, their problem-solving strategies or steps, which are fundamental skills (Hatay & Cihangir, 2021), are noteworthy because of the nature of mathematics. During mathematics lessons, students apply these strategies to real-life situations and arrive at solutions with ease (Aydın, 2019). This teaching is based on five basic principles: higher-order thinking, in-depth learning of information, making connections with the real world, sharing ideas, and providing social support (Newmann & Wehlage, 1993). Authentic learning activities equip students with the high-level skills required in mathematics. Possessing these skills has a positive impact on students' mathematical achievements (Ayotola & Adedeji, 2009; Hackett, 1985). It aids in the development of individuals who have high confidence in their mathematical abilities, are interested in mathematics, focus on problem-solving, and use their mathematical skills effectively (Echazarra et al., 2016).

The authentic learning approach develops students' mathematical thinking skills based on reasoning (Umay, 2003). The main objective of mathematics education is to equip students with reasoning skills that involve making observations, assumptions, logical inferences based on certain assumptions, and reasoning (Mullis et al., 2020). Reasoning encompasses various functions such as theory construction, systematization, and discovery in mathematics. Reasoning underlies the rules and procedures in mathematics and is used to establish facts rather than experimentation and observation (Umay & Kaf, 2005, p.188). Mathematical reasoning enables deep learning (Stylianides, 2010, p.44) and involves a high-level thinking process that elaborates and makes sense of a problem or situation by asking "Why" and "How" questions (Erdem, 2011, p.15). Critical and creative thinking are prerequisites for reasoning. Reasoning is the final step in the thinking process and is a crucial aspect of mathematical thinking (Umay, 2003, p.235). To develop reasoning skills, it is essential for students to interact , generate and share ideas. Teachers can facilitate the development of mathematical reasoning by encouraging collaborative work and presenting problems that require reasoning. Additionally, students should be given the opportunity to solve problems independently. The aim is to create an environment in which students can justify their ideas (Lithner, 2008). By engaging in cooperative learning within an authentic learning environment, students can exchange ideas with their peers and generate multiple solutions to

problems (Aydın, 2019). In conclusion, the use of an authentic learning approach in mathematics lessons is highly significant.

Based on the effect of authentic learning on mathematics achievement and reasoning skills, this study aimed to answer the question "What is the effect of using activities based on authentic learning approach used in mathematics courses on the academic achievement and reasoning skills of middle school students?". To this end, answers the following questions were sought:

1. Is there a significant difference in academic achievement gain scores between the experimental and control group students who were exposed to authentic learning activities in a mathematics course?
2. Is there a significant difference in reasoning skill gain scores between students in the experimental group, who participated in authentic learning activities during their mathematics course, and those in the control group?

In mathematics education, it is extremely important that students develop not only rules and procedural skills but also mathematical reasoning and problem-solving skills. An authentic learning approach can contribute to the development of these skills by enabling students to learn mathematical concepts in real-world contexts through meaningful activities. Therefore, an experimental study examining the effects of authentic learning on mathematics achievement and reasoning skills would make important contributions to the field of education. Such a study could provide guidance to teachers and educators on how to effectively implement authentic learning strategies to improve students' academic performance and problem-solving skills. It can also provide a basis for exploring ways of integrating authentic learning into the mathematics curriculum and examining the long-term effects of this approach. The findings of this study can lead to reform efforts in mathematics education and the adoption of student-centered teaching methods.

Method

Research Model

This study investigated the impact of activities based on an authentic learning approach on the academic achievement and reasoning skills of middle school students of mathematics. The study employed a quasi-experimental design, specifically the pretest-posttest paired control group model. The dependent variable was measured for participants before and after the experimental procedures (Büyüköztürk, 2011).

Lesson plans were prepared for the experimental and control groups before the application, considering the learning outcomes of the mathematics course. The teaching activity was then conducted within this framework. The experimental group underwent teaching activities based on authentic learning for the relevant outcomes within the research framework. In the control group, the teaching activity was conducted according to the curriculum. Tools based on academic achievement and reasoning skills were used to conduct the study both before and after the experimental process. In experimental design studies, the groups related to the subject being researched were matched as closely as possible (Johnson, & Christensen, 2012).

Table 1. Research Model

Group	Pretest	Independent Variable	Posttest
E	T1, T2	X	T1', T2'
C	T1, T2		T1', T2'

The table above shows the pretest-posttest paired control group design model of the study. E indicates the experimental group and C indicates the control group. T1 and T2 indicate the mathematics achievement and mathematical reasoning tests taken by the groups. Both tests were administered to the two groups as pre-test and post-test. X represents the independent variable of the study, which is the authentic learning activities implemented in the mathematics course.

Study Group

Study participants were selected using a convenience sampling technique. Due to time and resource constraints, the researchers conducted the research in their own classrooms using convenience sampling. The research was conducted during the first semester of the 2022-2023 academic year in two different classes: one control and one experimental, at an average public secondary school in Selçuklu district of Konya province. The researchers themselves developed and conducted the activities and teaching plans. The control group consisted of 33 students, whereas the experimental group had 26 students. To determine the study group, a pretest was administered to all classes at the relevant-grade level in the research school. The experimental and control groups were defined as relatively equivalent. The study employed a quasi-experimental design, and the participants were not selected completely randomly.

Instruments

The study data were collected using two instruments: the Academic Achievement Test and the Reasoning Skills Test. The researchers developed the academic achievement test, while the reasoning skills test was adapted from Pilten's (2008) test items. Please see the following for further details on both instruments.

Development of a Math Academic Achievement Test

The process of developing the academic achievement test is explained below with its steps.

1. Purpose of the developed test: This test measures the academic achievement of students of mathematics. The test covers the learning outcomes of the units Whole Numbers, Operations with Fractions, and Decimal Representations in the first semester of the sixth-grade mathematics course. The topic of fractions was selected because of the challenges students face in comprehending this area of learning.

2. Determining the characteristics to be measured using the test: The test determined the extent to which students acquired the 17 learning outcomes of the sixth-grade mathematics course. At least one question was included for each behavior in the draft instrument.

3. Writing the items The items were prepared by considering the learning outcomes specified in the 6th grade 1st semester of the MoNE mathematics curriculum for the 2022-2023 academic year. The questions were designed with attention to the cognitive level of the learning outcomes and were selected from the central exam (scholarship) question pool conducted by the Ministry of National Education in previous years. The researchers who evaluated the draft items were specialists in measurement, evaluation, and mathematics education. The pilot form was designed on the basis of expert opinions and consists of 31 multiple-choice items. Each item has four options.*4. Conduct the trial application.* The test form was administered to 102 students in a higher grade (7th grade) at a different secondary school where the learning activity related to these learning outcomes had been conducted previously. Item discrimination and difficulty indices were calculated for the test items. After analysis, five items were removed from the test because of low discrimination indices. This study aimed to determine if this version of the academic achievement test resulted in any deficiencies in the assessment of outcomes. The results indicated that a final test comprising 26 items covering the objectives could be administered. The KR20 value for the entire test was calculated to be 0.83, and the discrimination values of the test items ranged from 0.33 to 0.68, indicating an average level of difficulty. Table 2 displays the item discrimination indices.

Table 2. Academic Achievement Test Item Discrimination Indices

	i2	**i3**	**i4**	**i5**	**i6**	**i8**	**i9**	**i10**	**i11**
rjx	0.53	0.51	0.45	0.51	0.68	0.42	0.42	0.33	0.61
	i12	**i13**	**i14**	**i18**	**i19**	**i20**	**i21**	**i22**	**i23**
rjx	0.37	0.56	0.51	0.41	0.39	0.45	0.62	0.54	0.51
	i24	**i25**	**i26**	**i27**	**i28**	**i29**	**i30**	**i31**	
rjx	0.50	0.47	0.50	0.40	0.44	0.39	0.32	0.47	

rjx: item discrimination ix: item number

5. Scoring the answer sheets and item analysis.

The scoring key was used to score the answer sheets. Incorrect answers were given a score of 0, whereas correct answers were given a score of 1. The students' answer sheets were then analyzed.

Reasoning Skills Test

The "Reasoning Skill Test" used to assess mathematical reasoning skills was adapted from a test developed by Pilten (2008). The test was created for use in a doctoral dissertation titled 'The effect of teaching metacognitive strategies on the mathematical reasoning skills of primary school fifth grade students'. The test consists of 41 items. These items consist of open-ended and multiple-choice questions that include the qualities of Identifying and using appropriate reasoning, recognizing and using mathematical patterns, recognizing different representations of the same data, logical arguments, prediction, decision making, generalization, and non-routine problems. While the reliability of the test was 0.87, the test-retest reliability was calculated as 0.76. The measurement tool, which was reorganized within the scope of this research, includes 24 items that examine the achievements of the subjects in "Whole Numbers, Fractions, Decimal Fractions."

Procedure/ Process

Students in the experimental group were subjected to teaching procedures based on the authentic learning approach on fractions. In this context, students were asked to address problems related to fractions that they might encounter in real life and to develop solutions. Students had to resort to fraction operations for real-life experiences. In this process, the students had to understand, compare, transform, and use fraction concepts in operations. The teacher only acted as a guide, allowing the students to construct their own learning. Through this authentic learning experience in a real-world context, the students learned fractions in a more meaningful and lasting way.

Students in the control group were taught traditional teaching methods. The fraction topic was taught through abstract examples and exercises using a teacher-centered approach. The teacher conveyed fraction concepts, operations, and rules by writing on the board and solving questions. The students were then asked to complete the exercises and assignments in the textbook. These exercises often included numerical examples and problems. Students had to memorize only abstract concepts and operations without directly experiencing the real-life uses and applications of fractions. The teacher provided the correct answers and formulas, while the students passively listened and took notes.

Data Collection

Before the experimental procedure, both groups were given a mathematics achievement and reasoning skills test to assess their existing competencies related to the mathematics course objectives. After the 9-week experimental period, the same test was administered as a post-test for both groups.

Data Analysis

The study analyzed quantitative data for the subproblems related to the main research purpose. The data was organized using Excel. Statistical package programs were used to analyze the first and second subproblems. The data collected with the Academic Achievement Test and Reasoning Skills Test were compared using the dependent t-test (paired samples t-test). The study used a dependent t-test to determine if there was a significant difference between the pretest and posttest scores. In addition, an independent sample t-test was used to compare the academic achievement and reasoning skill scores of the experimental and control groups before and after the study. The significance of the difference between the academic achievement and reasoning skill achievement scores of the experimental and control groups students was tested using the independent t-test.

Ethical Considerations

Within the scope of this research, all activities were conducted in accordance with the Scientific Research and Publication Ethics procedures of Higher Education Institutions. Teaching activities were

based on teaching plans determined within the experimental process. The study was approved by the Necmettin Erbakan University Social Sciences Ethics Committee (Date, 14/10/2022; Decision No, 2022/349)

Findings

Descriptive Findings

This section presents the results of the analysis of the data collection tools used in the study for the experimental and control groups. Table 3 shows the pre-test and post-test score statistics for academic achievement and reasoning skills of both groups.

Table 3. Descriptive Statistics for Academic Achievement and Reasoning Skills Tests

	Academic Achievement Test				**Reasoning Skills Test**			
	Pre-test		**Post-test**		**Pre-test**		**Post-test**	
	$\bar{X}$	**sd**	$\bar{X}$	**sd**	$\bar{X}$	**sd**	$\bar{X}$	**sd**
Experimental Group	3.73	1.61	17.69	4.78	3.07	0.95	16.03	3.86
Control Group	2.67	0.99	14.12	2.31	3.20	1.22	7.44	3.22

The table shows that both groups had similar academic achievement test scores before the application, and both groups showed an increase in the post-test. However, the experimental group showed a higher increase than the control group. Furthermore, it was observed that the achievement levels of both study groups in the reasoning skills test were similar before application. However, there was an increase in both groups after post-test application. The experimental group showed a greater increase than the control group.

Findings Related to the First Sub-Problem

The first sub-problem of the study aimed to determine whether there was a significant difference in academic achievement gain scores between the experimental group, which received authentic learning activities in their mathematics course, and the control group. To answer this question, the academic achievement gain scores of both groups were analyzed using an independent t-test. Table 3 presents the t-test statistics for these results.

Table 4 displays the statistics for the participants' academic achievement attainment scores.

Table 4. Statistics of Participants' Academic Achievement Attainment Scores

Group	**n**	$\bar{X}$	**sd**	***t***	***Cohen's d***
Experimental Group	26	13.96	4.43	2.76	0.73
Control Group	33	11.46	2.44		

The table shows a difference in favour of the experimental group in their average academic achievement gain scores. The t-test results indicate a significant difference ($p<0.01$) due to the authentic learning activities implemented in the mathematics course. It can be concluded that the academic achievement of the experimental group students was significantly improved.

Findings Related to the Second Sub-Problem

The second sub-problem of the study aimed to determine whether there was a significant difference between the reasoning skills achievement gain scores of the experimental and control group students in

which authentic learning activities were applied in mathematics courses. To answer this question, the reasoning skills achievement scores of the groups were analyzed using an independent t-test. The t-test statistics for these results are presented in Table 5.

Table 5. Statistics of the Participants' Reasoning Skills achievements Scores

Group	n	$\bar{X}$	sd	t
Experimental Group	26	13.34	3.12	11.01
Control Group	33	4.36	3.09	

The table shows a significant increase in the average reasoning skills achievement scores of the participants in the experimental group compared with the control group ($p<0.01$). This result indicates that the application of authentic learning activities in the mathematics course had a positive impact on the reasoning skills of the experimental group students.

Discussion and Conclusion

The objective of this study was to investigate the impact of activities based on an authentic learning approach in middle school mathematics courses on students' academic achievement and reasoning skills.The first sub-problem of the research aimed to determine whether there was a significant difference in academic achievement scores between the experimental group students and the control group students in a mathematics course where authentic learning activities were applied. The conclusion drawn was that the implementation of authentic learning activities had a positive impact on students' academic achievement. Providing mathematics lesson outcomes with activities associated with daily life enables students to make sense of the lesson, thus supporting permanent learning. These findings are supported by various studies from different perspectives.

Upon examining the literature on authentic learning, it was observed that the use of authentic learning activities in mathematics lessons was limited. Blum's (2002) experimental study found that the use of authentic learning experiences in mathematics lessons had a positive effect on students' learning and attitudes. Aydn (2019) conducted a study to examine the effect of authentic learning environments on fourth-grade mathematics course success and students' academic self-confidence. This study evaluated the results of the Mathematics Achievement Test and Academic Self-confidence Scale. The conclusion drawn was that authentic learning activities increased students' course achievements and academic self-confidence. The study by Dadlı (2017) and Aynas (2018) discussed authentic learning activities in science teaching and concluded that they have a positive impact on students' academic achievement, attitudes toward the course, and problem-solving skills. The study also found that permanent learning was achieved. Aydn-Aşk (2016) suggests that incorporating authentic learning activities into mathematics lessons can lead to more efficient use of teaching time and support student success. Various studies have highlighted the importance of authentic learning activities in supporting success. Factors such as providing an enjoyable learning environment (Önger, 2019; Balcı, 2021), maintaining motivation (Gürdoğan, 2014), contributing to a positive classroom environment (Horzum & Bektaş, 2012; Hamurcu, 2016), and supporting problem-solving skills have been identified as significant contributors. Johnson and Christensen (2012) conducted a study with emergency management students and found that the use of disaster simulation provided an authentic learning environment and contributed positively to students' learning. Bhagat and Huang (2018) concluded that technology-based applications were successful in addition to basic curriculum subjects.

The study's second sub-problem aimed to determine whether there was a significant difference in reasoning skill achievement scores between the experimental group students, who were exposed to authentic learning activities in their mathematics course, and the control group students. The results showed that the daily life problems used in the authentic learning process contributed to the development of students' reasoning skills. Enabling students to apply the problem-solving method they learned in the classroom to real-life situations can improve their reasoning skills. During this process,

students' elaboration, assumptions, and reasoning contribute positively to their development. studies on reasoning skills based on authentic learning approaches have limitations.
Kara-alşkan (2019) observed that successful students generally used creative reasoning processes when solving non-routine mathematics problems similar to authentic learning activities. Similarly, Mutluoğlu (2009) found that virtual manipulatives used in geometry and measurement had a positive impact on the geometric reasoning of intermediate- and high-achieving mathematics students. According to Dolapcioglu and Doğanay (2022), the teacher's preparation for such experiences is considered a crucial first step.
As demonstrated in our study, other studies on authentic learning methods have also found that such practices enhance academic achievement across multiple courses and promote lasting learning. Furthermore, our study distinguishes itself from others by demonstrating the positive impact of authentic learning activities on students' reasoning skills in mathematics lessons. As a result, the use of authentic learning activities in mathematics courses had a positive impact on students' academic achievement and reasoning skills.

Recommendation

In this section, some suggestions are included in line with the findings and results obtained from the current research.

- Because such activities take a long time, evaluations regarding the time part of the activities in the plan can make the process more efficient.
- It is important to ensure that the problems included in the authentic learning environment are complex and have multiple solutions. Students should be encouraged to actively seek their own solutions within the learning environment.
- Because of the associations between authentic learning activities and daily life, studies on reasoning processes can provide valuable insights.
- To enhance the connection between mathematics lessons and real life, students are given authentic extracurricular tasks in addition to in-class activities.
- In our research, we enriched authentic learning activities with web-based tools. Therefore, incorporating technologically supported tools and materials for artificial authentic vehicles will enhance the learning process, making it more enjoyable and efficient.

Limitations

In this study, experimental research was conducted to examine the effectiveness of the authentic learning approach in mathematics courses. However, as with any research, this study has some limitations. First, the study was conducted in only one public school and excluded private schools or schools with different socioeconomic levels. This situation limits the generalizability of the results. In addition, the fact that the participants were selected only from 7th grade students does not adequately explain the effect of the authentic learning approach in different age groups. Finally, the study only measured students' academic achievement and reasoning skills, ignoring the effects of authentic learning on motivation, attitude, and retention. By highlighting the weaknesses of the study, it is noted that the results should be interpreted more carefully and their generalizability is limited to this context.

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