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The Effect of Mistake-Handling Activities on Academic Achievement and Critical Thinking of 9th Grade Students*

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Abstract

This study aims to examine the effects of Mistake-Handling Activities (MHA) on students' academic achievement and critical thinking skills of 9th-grade students. The research was conducted in a Science High School in Türkiye with 59 students and employed a quasi-experimental design with a non-equivalent pretest-posttest control group. While MHA was implemented in the experimental group, traditional teaching methods were used in the control group. The MHA activities were designed based on the 9th-grade topics and learning objectives outlined in the Ministry of National Education's (MEB) Secondary School Mathematics Curriculum. These activities consisted of open-ended questions and incorrect solutions related to these questions. Data were collected through students' academic achievement scores in mathematics and critical thinking skill scales. The findings of the study revealed that MHA significantly improved the academic achievement of students in the experimental group. A positive difference was observed between the pretest and posttest academic achievement scores of the experimental group, whereas no such improvement was detected in the control group. The posttest results of the critical thinking skills scale also indicated a significant difference between the groups in favor of the experimental group. These results suggest that errors should not be considered merely as inaccuracies to be corrected in the teaching process but also as tools that foster learning. MHA facilitated the development of students' critical thinking skills through cognitive conflict. Based on the study's findings, it is recommended that MHA be adapted to other subjects and different age groups to expand its implementation. Furthermore, teachers

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should be encouraged to receive training on effectively applying this approach in their instructional practices.

Keywords: Mistake-Handling Activity (MHA), learning from mistakes, academic achievement, critical thinking

Öz

Bu araştırma, hata temelli aktivitelerin (HTA) 9. sınıf matematik öğretiminde öğrencilerin akademik başarısı ve eleştirel düşünme becerileri üzerindeki etkilerini incelemeyi amaçlamaktadır. Araştırma, Türkiye'deki bir fen lisesinde 59 öğrenci üzerinde gerçekleştirilmiş olup, eşitlenmemiş öntest-sontest kontrol gruplu yarı deneysel desen kullanılarak yürütülmüştür. Araştırmanın deney grubunda HTA uygulanırken, kontrol grubunda geleneksel öğretim yöntemleri kullanılmıştır. HTA uygulamaları MEB Ortaöğretim Matematik Dersi Öğretim Programındaki 9. sınıf konu ve kazanımları dikkate alınarak hazırlanmış açık uçlu sorulardan ve bunlara ait hatalı çözümlerinden oluşmaktadır. Veriler, öğrencilerin matematik dersine ilişkin akademik başarı puanları ve eleştirel düşünme beceri ölçekleri aracılığıyla toplanmıştır. Araştırmanın bulguları, HTA uygulamalarının deney grubundaki öğrencilerin akademik başarılarını anlamlı bir şekilde artırdığını ortaya koymuştur. Deney grubu öğrencilerinin öntest ve sontest akademik başarı notları arasında pozitif bir fark görülürken, kontrol grubunda bu yönde bir gelişme saptanmamıştır. Ayrıca, HTA'nın eleştirel düşünme becerilerini geliştirdiği ve öğrencilerin problem çözme, sorgulama ve analiz yeteneklerini artırdığı belirlenmiştir. Deney grubundaki öğrenciler, hatalardan öğrenme sürecinde, hataların nedenlerini sorgulayarak kavramsal öğrenmeyi derinleştirmiştir. Bu sonuçlar, hataların öğretim sürecinde yalnızca düzeltilmesi gereken yanlışlıklar olarak değil, aynı zamanda öğrenmeyi teşvik eden araçlar olarak değerlendirilmesi gerektiğini göstermektedir. HTA, öğrencilerin bilişsel çatışma yoluyla eleştirel düşünme ve problem çözme becerilerini geliştirmesini sağlamıştır. Araştırma bulguları, literatürde yer alan HTA'nın etkilerini destekler nitelikte olup, özellikle matematik eğitiminde bu yöntemlerin uygulanabilirliğini ve etkinliğini ortaya koymaktadır. Araştırma sonucunda, HTA'nın diğer derslere ve farklı yaş gruplarına uyarlanarak yaygınlaştırılması ve öğretmenlerin bu yöntemi etkili bir şekilde uygulayabilmeleri için eğitim almalarının teşvik edilmesi önerilmektedir.

Anahtar Kelimeler: Hatalardan öğrenme, akademik başarı, eleştirel düşünme, hata temelli aktiviteler

Inroduction

Making mistakes and overcoming them is considered a natural part of the learning process. In mathematics education, errors made by students can be seen as opportunities to deepen the learning process and strengthen conceptual understanding (Brodie, 2014; Cooper, 2009). In the literature, errors are generally defined as the incorrect use or interpretation of mathematical expressions and ideas (Erbaş et al., 2010). However, these errors can serve not only as inaccuracies to be corrected but also as tools to foster critical thinking and enhance academic achievement (Brodie, 2014; Heinze, 2005).

Studies on student errors in mathematics education primarily focus on identifying errors and understanding the misconceptions underlying them. However, research on how errors should be addressed in teaching and learning processes is limited (Borasi, 1986; Gardee & Brodie, 2014; Heinze, 2005; Santagata, 2005). Early studies argue that errors made by students during the process of constructing knowledge should be considered opportunities for teaching.

Cognitive and constructivist approaches, which are widely used in education, offer different perspectives on student errors. According to the cognitive approach, errors should be viewed negatively, and students should focus on positive knowledge (Santagata, 2005). In contrast, the constructivist approach rejects this correctness-focused view and emphasizes the phenomenon of learning from mistakes and failures (Bichard, 2004). The concept known as "negative knowledge" not only helps students understand what they do not know but also enables them to develop higher-order thinking skills (Akpınar & Akdoğan, 2010; Parviainen & Eriksson, 2006).

Brodie (2014) noted that mathematical errors can be utilized by teachers to enhance students' conceptual understanding and provide access to the nature of mathematical knowledge. Learning from errors occurs when students analyze and correct their mistakes and reflect on their misconceptions (Tulis, Stuer, & Dresel, 2015). Borasi (1986) regarded errors as a springboard in mathematics teaching and argued that this approach could be a powerful tool for diagnosing and improving learning difficulties. Heinze (2005) also emphasized that learning from errors is a method for developing inquiry, critical thinking, and various reasoning strategies in students. Accordingly, instead of merely correcting errors in mathematics teaching, in-class activities can be organized to help students understand the reasons behind these errors and prevent them from repeating similar mistakes. Such activities can enrich students' learning processes and provide a more permanent and effective educational experience.

Mistake-Handling Activities (MHA), which are aligned with the constructivist approach, are activities designed to encourage students to analyze misconceptions and construct new knowledge. These activities aim not only to convey correct information but also to use incorrect information and errors as part of the learning process. Heinze and Reiss (2007) stated that MHA supports the concept of negative knowledge, helping individuals understand what they should not do and fostering critical thinking skills. Parviainen and Eriksson (2006)

described negative knowledge as a complementary tool that supports both cognitive and affective skills in individuals. The constructivist approach in education advocates using errors as a learning tool. In this context, learning environments that allow students to analyze their errors not only enhance the process of knowledge acquisition but also improve students' critical thinking skills (Borasi, 1994).

Research on the effects of MHA in mathematics education shows that these activities enhance both students' academic success and their conceptual understanding (Gedik Altun & Morkoyunlu, 2023; Gedik et al., 2017; Özkaya & Konyalıoğlu, 2019; Özkaya, 2015; Sancar & Özkaya, 2019). Although studies on the effectiveness of MHA have been increasing, research that specifically investigates the impact of these approaches on critical thinking skills in ninth-grade mathematics education remains limited. For example, Gedik et al. (2017) stated in their study that MHA improved students' critical thinking skills and increased their motivation to learn. Similarly, Özkaya (2015) highlighted the positive effects of MHA on student achievement and its contribution to teachers adopting a more constructive approach to student errors. Türkdoğan and Baki (2013) observed that the classroom use of errors reduced students' conceptual misconceptions and improved their mathematical thinking skills. While these studies provide strong theoretical support for MHA, further research is needed to explore its application processes and classroom effects. The current literature highlights several critical gaps that motivate this study. First, although the theoretical underpinnings of MHA are well established, there is no empirical evidence regarding its effectiveness in enhancing critical thinking skills—particularly among secondary-school students (Gedik et al., 2017). Second, existing research that simultaneously examines the influence of MHA on both students' academic achievement and critical thinking skills in mathematics learning remains insufficient. Third, studies offering practical examples of how these activities can be effectively implemented at the ninth-grade level, within standard curriculum requirements, are limited. This study addresses these gaps by investigating the combined effect of MHA on both academic achievement and critical thinking skills in the context of ninth-grade students. In doing so, it seeks to provide valuable insights for researchers and practitioners interested in employing error-based activities in mathematics education, supplying experimental evidence on the practical application and outcomes of MHA in a specific and crucial educational setting. The main problem of this study seeks to answer the question of how mistake-handling activities influence students' academic achievement and critical thinking skills in 9th-grade mathematics education. The sub-problems that aim to address this main problem are structured as follows:

- Is there a significant difference in the pre-test and post-test scores of academic achievement between the experimental group and the control group after the implementation of MHA?
- Is there a significant difference between the pre-test and post-test scores of critical thinking skills for the experimental group students after the implementation of MHA?

- Is there a significant difference in the pre-test and post-test scores of critical thinking skills between the experimental group and the control group students after the implementation of MHA?

Method

Research Methodology

This study adopted a quantitative approach and employed a non-equivalent pre-test and post-test control group quasi experimental design. This design was intentionally selected because it enables the investigation of cause-and-effect relationships in educational settings where random assignment of students to groups is not feasible due to existing classroom structures (Karasar, 2012). Since our aim was to examine, within intact classroom environments, the effect of a specific instructional approach (HTE) on both academic achievement and critical thinking skills, this design offered the most suitable framework for our research context. Karasar (2012) characterizes the quasi-experimental design as a research model that, while acknowledging the constraints of working with pre-formed groups, allows researchers—under their direct control—to generate data for establishing causal relationships.

Study Group

To conduct an in-depth investigation on students with sufficient prior knowledge, the sample of this study was selected using purposive sampling, a non-random sampling method. The 9th-grade level was chosen because it is a critical period when students transition to high school education and their mathematical thinking skills develop rapidly. Students at this level may be more open to mistake-handling approaches as they have not yet developed rigid beliefs about mathematical concepts. The research was conducted at a Science High School in a provincial center in Türkiye during the 2017–2018 academic year. This school type was preferred because the students have high mathematical competence, allowing the effect of MHA on critical thinking skills, rather than basic mathematical skills, to be observed more clearly. Accordingly, the quantitative data for the study were collected from 59 students studying in two intact 9th-grade classes. One class (29 students) was designated as the experimental group, while the other class (30 students) was designated as the control group.

Data Collection Tools

Academic achievement scores (AAS): To measure students' mathematical achievement, written exam scores obtained from the Ministry of National Education's e-school system were used. Fall semester mathematics exam scores were considered as pre-test scores, while spring semester mathematics exam scores were used as post-test scores.

Critical thinking skills scale (CTSS): In this study, students' critical thinking dispositions were measured with the Critical Thinking Skills Questionnaire (CTSQ) developed by Sarıgöz (2014). The instrument was derived from the California Critical Thinking Disposition Inventory

designed by Facione (2000) and subsequently adapted to Turkish by Kökdemir (2003). Consisting of 22 items rated on a five-point Likert scale (1 = "Strongly Disagree" to 5 = "Strongly Agree"), the questionnaire has demonstrated acceptable internal consistency, with a Cronbach's alpha of .80 (Sarıgöz, 2014). The CTSQ assesses multiple facets of critical thinking—such as analytic reasoning, open-mindedness, and inquisitiveness—and higher scores reflect stronger critical thinking dispositions.

Preparation of MHA Questions and Solutions

MHAs were developed as open-ended questions accompanied by deliberately incorrect solutions, taking into account the ninth-grade topics and learning objectives specified in the Turkish Ministry of National Education's Mathematics Curriculum for Science High Schools. In line with Melis's (2005) recommendation that erroneous examples mirror students' prevalent misconceptions and mistakes, the design drew on empirical studies that document the conceptual difficulties, errors and obstacles frequently encountered by ninth-grade learners (Cangelosi, Madrid, Cooper, Olson, & Hartter, 2013; Çetin, 2009; Şandır, Ubuz, & Argün, 2002). Because the MHA format also requires expert-generated errors beyond student misconceptions, existing MHA items in the literature (Gedik, 2014; Gedik et al., 2017; Özkaya, 2015; Özkaya, Konyalıoğlu, & Gedik, 2013; Shabanifar, 2014) and specialist opinions were consulted in constructing the questions and erroneous solutions. The resulting materials were reviewed for content validity and clarity by two mathematics-education scholars and an experienced secondary teacher; revisions were made on the basis of their feedback before classroom implementation. MHAs were integrated into regular mathematics lessons for one class period each week over an eight-week span. Table 1 presents the weekly topics and the number of MHA items administered. In every session, at least two open-ended problems and their unlabeled incorrect solutions were displayed on the interactive whiteboard, after which students were asked, "Is there an error in this solution? If so, what is the source of the error?" Student responses were then collected and discussed.

Example MHA Question

Given $-2 < x < 5$ determine the widest interval of values attained by the expression $x^2 - 2x + 3$.

Presented Incorrect Solution

To find $\boldsymbol{x^2}$, each part of the inequality $\boldsymbol{-2} < x < 5$ is squared:

$\boldsymbol{4} < \boldsymbol{x^2} < 25$ **……**(I) bulunur.

To obtain $\boldsymbol{-2x}$, each part of $\boldsymbol{-2} < x < 5$ is multiplied by −2:

$\boldsymbol{-10} < -2\boldsymbol{x} < 4$ **……**(II) . Adding (I) and (II) term-by-term yields

$\boldsymbol{4} < \boldsymbol{x^2} < 25$

$+\ \ -\mathbf{10} < -2\boldsymbol{x} < 4$

$-\mathbf{6} < \boldsymbol{x}^{\mathbf{2}} - \mathbf{2}\boldsymbol{x} < 29$ ……(III) bulunur.

Finally, adding +3 to each part of (III) gives $-\mathbf{3} < \boldsymbol{x}^{\mathbf{2}} - \mathbf{2}\boldsymbol{x} + \mathbf{3} < 32$.

Hence, the expression $-\mathbf{3} < \boldsymbol{x}^{\mathbf{2}} - \mathbf{2}\boldsymbol{x} + \mathbf{3} < 32$ is asserted to take values in the interval (-3,32).

Error Analysis

This erroneous solution enables students to realise that (i) squaring an interval that contains zero may yield a minimum of 0, (ii) the intervals of terms involving the same variable cannot be combined through direct addition, and (iii) functional strategies such as completing the square are essential for determining the range of the expression.

Table 1. Weekly MHA topics and number of questions

Week	Topic	MHA Question Count
1	Exponential and Radical Expressions	3
2	Division and Divisibility Rules	2
3	Ratio and Proportion	2
4	Inequalities	2
5	Inequalities	2
6	Number Sets & Proof	3
7	Number Sets & Proof	2
8	Number Sets & Proof	4

Data Analysis

To determine pre-test and post-test academic achievement scores, the average mathematics exam scores obtained from the Ministry of National Education's e-school system were calculated using Excel for each group of students. Fall semester average scores were used for pre-test academic achievement scores, while spring semester averages were used for post-test academic achievement scores. The Critical Thinking Skills Scale was administered to both the experimental and control groups as both pre-test and post-test. Responses to the scale items were arranged on a 5-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree." Positive items were scored from 1 to 5, while negative items were reverse-scored from 5 to 1. A critical thinking skills score was calculated by dividing the total score obtained by the total number of items answered (Turgut & Baykul, 1992). All students completed every item on the scale. Scores on the instrument range from 1 (minimum) to 5 (maximum), with higher scores indicating stronger critical-thinking skills.Dependent and independent t-test analyses were performed using SPSS 22.0 software to compare the AAS and CTSS scores within and between the experimental and control groups.

Findings

The study investigated how MHA implementations in 9th-grade mathematics education impact students' academic achievement and critical thinking skills. To answer the research sub-problems, quantitative data obtained before and after the implementation were analyzed, including pre-test and post-test AAS and pre-test and post-test CTSS of the groups.

Findings Related to the Academic Achievement Scores of the Experimental and Control Groups

One of the objectives of this study is to examine the effect of mistake-handling activities on students' academic achievement during the teaching process. The findings obtained from the fall semester written exam averages as "pre-test academic achievement scores" and the spring semester written exam averages as "post-test academic achievement scores" are presented below.

Initially, a normality test was applied to the data obtained from the pre-test and post-test academic achievement scores of the groups. Since the number of students participating in the groups was 50 or fewer, the Shapiro-Wilk test was used for the normality test. The results of the Shapiro-Wilk normality test for the groups are shown below.

Table 2. Shapiro-wilk normality test results for pre-test and post-test aas of experimental and control groups

Groups	AAS	N	$\bar{X}$	Ss	S.K.	p
Experimental	Pre-test	29	79.93	15.01	-0.899	0.023
	Post-test	29	78.19	11.37	0.016	0.123
Control	Pre-test	30	76.58	16.28	-0.704	0.138
	Post-test	30	61.82	16.39	0.158	0.201

According to the Shapiro-Wilk test results in Table 2, the pre-test academic achievement scores show that the p-value is less than 0.05 for the experimental group, while it is greater than 0.05 for the control group. However, relying solely on the p-value for interpreting normality is considered insufficient. Therefore, the skewness coefficient (S.K.) was also used to assess normality. If the skewness coefficient is within the range of -1 to +1, it can be interpreted that the data do not exhibit extreme deviations from normal distribution (Büyüköztürk, 2007).

Based on this criterion, as shown in Table 2, the skewness coefficients of the experimental and control groups are within the range of -1 to +1. Thus, it can be concluded that the pre-test AAS of both the experimental and control groups follow a normal distribution. Similarly, for the post-test AAS, the p-values are greater than 0.05, and the skewness coefficients are also within the range of -1 to +1. Therefore, it can be concluded that the post-test AAS of the experimental and control groups follow a normal distribution.

Since the data follow a normal distribution, an independent t-test was used to determine the significance of differences between the pre-test academic achievement scores of the groups before the implementation. The findings obtained from the independent t-test are presented in Table 3.

Table 3. Independent t-test results for pre-test aas of experimental and control groups

Grups	N	$\bar{X}$	Ss	t	p
Experimental	29	79.93	15.204	0.816	0.418
Control	30	76.18	16.283		

According to Table 3, the p-value is found to be 0.418. Based on this p-value, it was determined that there is no statistically significant difference between the pre-test academic achievement scores of the experimental and control groups ($p > 0.05$). This result supports the assumption that the groups were equivalent before the implementation, which is essential for evaluating the relationship between the post-test academic achievement scores of the groups.

Table 4. Independent t-test results for post-test aas of experimental and control groups

Groups	N	$\bar{X}$	Ss	t	p
Experimental	29	78.19	11.372	2.137	0.037
Control	30	61.82	16.391		

As seen in Table 4, the p-value is 0.037. Based on this p-value, it can be concluded that there is a statistically significant difference between the post-test academic achievement scores of the experimental and control groups ($p < 0.05$). This significant difference, despite the decrease in the post-test AAS averages, is in favor of the experimental group. This finding is corroborated by an analysis of the groups' mean academic scores. Although both groups exhibited an overall decline during the spring term, the experimental group sustained a higher level of academic performance, aligning with the positive influence of MHA on students' mathematical understanding.

Findings Related to the Critical Thinking Skills Scale Scores of the Experimental and Control Groups

This section presents the findings related to the study's second and third sub-problems, both of which pertain to critical-thinking skills. For this purpose, the CTSS was administered to both the experimental and control groups as a pre-test and post-test before and after the implementation. Based on the principle that the score obtained from the CTSS is calculated by dividing the total score of the items marked by a student by the total number of marked items (Turgut & Baykul, 1992), the findings were derived from these calculations.

Initially, a normality test was conducted on the data obtained from the pre-test and post-test CTSS scores of the groups. Given the number of students participating in the groups, the Shapiro-Wilk test was used for the normality test. The results of the Shapiro-Wilk normality test for the groups are presented below.

Table 5. Shapiro-wilk normality test results for pre-test and post-test ctss scores of experimental and control groups

Groups	CTSS	N	$\bar{X}$	Ss	Ç.K.	P
Experimental	Pre-test	29	3.69	0.425	0.006	0.458
	Post-test	29	3.83	0.327	0.528	0.223
Control	Pre-test	30	3.73	0.273	-0.425	0.813
	Post-test	30	3.41	0.445	-0.711	0.465

According to Table 5, the pre-test p-values for both the experimental and control groups indicate that the CTSS pre-test scores follow a normal distribution ($p > 0.05$). Similarly, the post-test p-values for both groups also indicate a normal distribution ($p > 0.05$). Furthermore, the skewness coefficients (S.K.) for the pre-test and post-test CTSS scores of both groups fall within the range of -1 to +1, confirming that the data do not exhibit extreme deviations from normal distribution.

To address the study's second sub-problem, we investigated whether a significant difference existed between the experimental group's pre-test and post-test critical-thinking scores after the MHA intervention. For this purpose, a paired t test, a statistical procedure explicitly designed to compare two measurements taken from the same group at different time points, was employed. The findings from the paired t-test are presented in Tables 6 and 7.

Table 6. Mean and standard deviation results for pre-test and post-test ctss scores of experimental and control groups

Gruplar	N	Pre-Test		Post-Test	
		$\bar{X}$	Ss	$\bar{X}$	Ss

Experimental	29	3.69	0.425	3.83	0.327
Control	30	3.73	0.273	3.41	0.445

As shown in Table 6, the pre-test mean CTSS score for the experimental group was 3.69, while the post-test mean score increased to 3.83. For the control group, the pre-test mean CTSS score was 3.73, which decreased to 3.41 in the post-test. These results indicate a slight increase in the mean CTSS score for the experimental group after the implementation, while a decrease is observed for the control group. Furthermore, although the control group had a higher mean pre-test CTSS score than the experimental group, the experimental group achieved a higher mean post-test CTSS score.

Table 7. Paired t-test results for pre-test and post-test ctss scores of experimental and control groups

Groups	**CTSS**	**N**	$\bar{X}$	**t**	**P**
Experimental	Pre-Test	29	3.69	-1.608	0.119
	Post-Test	29	3.83		
Control	Pre-Test	30	3.73	3.876	0.001
	Post-Test	30	3.41		

According to Table 7, the p-value for the experimental group is 0.119. Although the mean post-test CTSS score of the experimental group increased, this p-value, being greater than the significance level of 0.05, indicates that the difference between the pre-test and post-test CTSS scores is not statistically significant ($p > 0.05$). For the control group, the p-value is 0.001, which is less than the significance level of 0.05. This indicates a statistically significant difference between the pre-test and post-test CTSS scores of the control group ($p < 0.05$). However, this significant difference favors the pre-test, as the mean pre-test CTSS score ($\overline{X} = 3{,}73$) is higher than the mean post-test score ($\overline{X} = 3{,}41$).

To address the study's third sub-problem, an independent t-test was conducted to examine the significance of differences between the pre-test and post-test CTSS scores of the experimental and control groups.

Table 8. Independent t-test results for pre-test ctss scores of experimental and control groups

Groups	CTSS	N	$\bar{X}$	Ss	t	p
Experimental	Pre-Test	29	3.69	0.425	-0.402	0.689
Control	Pre-Test	30	3.73	0.273		

As shown in Table 8, the p-value is 0.689, indicating no statistically significant difference between the pre-test CTSS scores of the experimental and control groups ($p > 0.05$). This result supports the equivalence of the groups before the implementation, aiding in the analysis of the relationship between the post-test CTSS scores of the groups.

Table 9. Independent t-test results for post-test ctss scores of experimental and control groups

Groups	CTSS	N	$\bar{X}$	Ss	t	p
Experimental	Post-test	29	3.83	0.327	4.040	0.00
Control	Post-test	30	3.41	0.447		

As shown in Table 9, the p-value is 0.000, which is less than the significance level of 0.05. This indicates a statistically significant difference between the post-test CTSS scores of the experimental and control groups ($p < 0.05$). This significant difference favors the experimental group based on the post-test mean scores.

Discussion, Conclusion and Suggestions

The findings of the study reveal that MHA have a significant effect on students' academic achievement. A notable improvement was observed in the pre-test and post-test AAS of students in the experimental group, while no such improvement was evident in the control group. This finding suggests that MHAs can enhance students' conceptual understanding and problem-solving skills.The data suggest that students in the experimental group effectively engaged in analyzing and correcting their mistakes, reinforcing their learning and achieving significant academic improvement. The impact of MHAs on academic achievement highlights how this approach deepens the learning process by enabling students to identify and correct

their errors. This finding aligns with previous research in the literature (Gedik Altun & Morkoyunlu, 2023; Heinze & Reiss, 2007; Özkaya & Konyalıoğlu, 2019; Sancar & Özkaya, 2019). Sancar and Özkaya (2024), who showed that EBA (error-based activity) presented in the fraction teaching of the sixth grade increased academic success permanently, also confirmed their results. Heinze and Reiss (2007) noted that using mistakes as a learning tool improves students' conceptual understanding and mathematical thinking skills. Similarly, Borasi (1989) emphasized that analyzing mistakes enhances students' problem-solving abilities.

MHAs allowed students to go beyond focusing solely on correct information by analyzing and correcting incorrect information as well. This approach deepened the learning process by developing students' cognitive skills, consistent with Bichard's (2004) "learning from mistakes" model. Furthermore, students in the experimental group demonstrated an increase in conceptual understanding by shifting from avoiding mistakes to meaningfully analyzing and addressing them.

The impact of HTA on critical-thinking skills is evident in the way students' capacity for questioning and analysis expanded, thereby strengthening their ability to tackle complex problems. In the present study, the observed gains stem from students' adoption of errors as learning resources: instead of merely correcting a wrong answer, they interrogated the underlying causes of each error and, in the process, devised new solution strategies. By fostering such habits of mind, the HTA approach equips learners to engage more effectively in future learning and problem-solving situations.

These findings align with and extend the existing literature. Our students displayed marked growth in identifying sources of error, testing alternative solutions, and defending their reasoning, mirroring the curiosity, critical stance, and heightened awareness reported for teachers in the study by Altun and Konyalıoğlu (2019). Consistent with the constructivist notion of negative knowledge (Parviainen & Eriksson, 2006), HTAs provide a structured opportunity to move beyond simple error correction toward analysing the reasons behind mistakes and developing novel strategies. This result echoes Borasi's (1994) claim that errors, by generating cognitive conflict, serve as a powerful vehicle for cultivating critical-thinking skills, as well as the findings of Gedik et al. (2017), who showed that mistake-handling activities sharpen students' questioning and problem-solving abilities.

Based on the findings of this study, the following recommendations are proposed:

1. **Teacher training on MHAs:** Professional development programmes should be designed for mathematics teachers to enable the effective implementation of MHAs, emphasising the creation of supportive classroom environments in which errors are viewed not as failures but as learning opportunities.

2. **Integration into curricula:** Mathematics curriculum developers should integrate structured MHAs into the curriculum, particularly in areas where students experience conceptual difficulties.

3. **Further research on MHAs:** Future studies should investigate the effects of MHAs across different age groups and subjects to develop broader implementation recommendations.

4. **Assessment Practices:** Schools should consider incorporating error-analysis components into mathematics assessments to foster the development of students' critical-thinking skills in addition to their content knowledge.

By adopting these recommendations, MHAs can be utilized as a powerful educational tool to foster students' academic and cognitive development in diverse learning environments.

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Geniş Özet

Hata Temelli Aktivitelerin 9. Sınıf Öğrencilerinin Akademik Başarıları ve Eleştirel Düşünmeleri Üzerindeki Etkisi

Giriş

Eğitim süreci, öğrencilerin yalnızca bilgi edinmeleri değil, aynı zamanda bu bilgileri anlamlandırmaları, analiz etmeleri ve eleştirel bir şekilde değerlendirebilmeleriyle etkin hâle gelir. Hata yapmak ve bu hatalardan ders çıkarmak öğrenme sürecinin doğal bir parçası olarak görülmektedir. Bu bağlamda öğrenme, hataların kaçınılması gereken unsurlar değil; öğrenmeyi tetikleyen bilişsel fırsatlar olarak değerlendirilmelidir. Özellikle matematik eğitiminde öğrencilerin yaptığı hatalar, yalnızca düzeltilmesi gereken yanlışlar değil; aynı zamanda öğrenmeyi derinleştiren, kavramsal anlayışı güçlendiren fırsatlar olarak değerlendirilmelidir.

Geleneksel öğretim anlayışında hatalar çoğunlukla düzeltilmesi gereken yanlışlar olarak görülürken, yapılandırmacı eğitim anlayışı hataları öğrenme sürecini derinleştiren araçlar olarak tanımlar. Bu bakış açısı, öğrencilerin kendi düşünme süreçlerini fark etmelerini ve hataların nedenlerini sorgulayarak anlamlı öğrenme gerçekleştirmelerini destekler. Son yıllarda özellikle matematik eğitiminde hata odaklı yaklaşımlar, öğrencilerin kavramsal anlayışlarını artırma, problem çözme becerilerini geliştirme ve eleştirel düşünme becerilerini destekleme amacıyla giderek daha fazla kullanılmaktadır.

Öğrencilerin hataları fark etmeleri, analiz etmeleri ve bu hatalardan çıkarımda bulunarak doğruya ulaşmaları, onların üst düzey bilişsel becerilerini harekete geçirir. Bu bağlamda geliştirilen Hata Temelli Aktiviteler (HTA), öğrencilerin yalnızca doğru bilgiye ulaşmalarını değil, aynı zamanda yanlış bilgiyi sorgulamaları yoluyla daha kalıcı ve derinlemesine öğrenme deneyimi kazanmalarını hedefler. HTA, özellikle öğrencilerin sık hata yaptığı kavramlara odaklanarak onlara yapılandırmacı öğrenme ortamlarında bilişsel çatışma yaşatmayı ve bu çatışma sayesinde öğrenmelerini desteklemeyi amaçlar.

Kuramsal Çerçeve ve Araştırmanın Gerekçesi

Bu çalışma, mevcut literatürdeki önemli boşlukları ele almaktadır. HTA' nın teorik temelleri güçlü olsa da, özellikle ortaokul öğrencileri arasında eleştirel düşünme becerilerini geliştirmedeki etkinliğine dair deneysel kanıtlar yetersizdir. Ayrıca, HTA' nın hem akademik başarı hem de eleştirel düşünme becerileri üzerindeki eş zamanlı etkisini inceleyen ve lise düzeyinde pratik uygulama örnekleri sunan araştırmalar sınırlıdır. Bu çalışma, HTA' nın 9. sınıf öğrencilerinin hem akademik başarıları hem de eleştirel düşünme becerileri üzerindeki etkisini araştırarak bu boşlukları gidermeyi ve hata tabanlı etkinlikleri matematik eğitiminde

kullanmak isteyen araştırmacılar ve uygulayıcılar için değerli bilgiler sunmayı hedeflemektedir.

Literatürde matematiksel hatalar genellikle öğrencilerin kavram yanılgılarını belirlemek amacıyla incelenmiş, ancak bu hataların öğretim sürecinde nasıl kullanılacağına yönelik araştırmalar sınırlı kalmıştır. Yapılandırmacı öğrenme yaklaşımı, hataları öğrenme fırsatları olarak değerlendirmekte ve öğrencilerin kendi yanlışlarını fark ederek anlamlı öğrenme gerçekleştirmelerini savunmaktadır. Bu kapsamda "negatif bilgi" kavramı, bireyin neyi yapmaması gerektiğini öğrenmesi yoluyla eleştirel düşünme ve üst düzey bilişsel beceriler geliştirmesini desteklemektedir. Borasi (1994) ve Heinze (2005), hataların analiz edilmesinin öğrencilerin kavramsal anlayışlarını ve problem çözme stratejilerini geliştirdiğini vurgulamıştır.

Son yıllarda yapılan bazı araştırmalarda (Özkaya, 2015; Gedik et al., 2017; Sancar & Özkaya, 2019) HTA'ların akademik başarıyı ve kavramsal farkındalığı artırdığı görülmüştür. Ancak bu çalışmalar çoğunlukla akademik başarıya odaklanmış, HTA'ların eleştirel düşünme becerileri üzerindeki etkisini bütüncül olarak ele alan az sayıda çalışma yapılmıştır. Bu çalışma, HTA' nın 9. sınıf öğrencilerinin hem akademik başarıları hem de eleştirel düşünme becerileri üzerindeki etkisini araştırarak bu boşlukları gidermeyi ve hata tabanlı etkinlikleri matematik eğitiminde kullanmak isteyen araştırmacılar ve uygulayıcılar için değerli bilgiler sunmayı hedeflemektedir.

Bu çalışmanın temel problemi, hata ele alma etkinliklerinin 9. sınıf matematik eğitiminde öğrencilerin akademik başarıları ve eleştirel düşünme becerilerini nasıl etkilediği sorusuna cevap aramaktır. Bu temel problemi ele almayı amaçlayan alt problemler şu şekilde yapılandırılmıştır:

- HTA uygulamaları sonrası deney grubu ile kontrol grubu öğrencilerinin akademik başarılarına yönelik öntest ve sontest puanlarında anlamlı bir fark var mıdır?
- HTA uygulamaları sonrası deney grubu öğrencilerinin eleştirel düşünme becerilerine yönelik öntest ve sontest puanları arasında anlamlı bir fark var mıdır?
- HTA uygulamaları sonrası deney grubu ile kontrol grubu öğrencilerinin eleştirel düşünme becerilerine yönelik öntest ve sontest puanları arasında anlamlı bir fark var mıdır?

Yöntem

Bu çalışma, nicel araştırma yaklaşımıyla yürütülmüş ve eşdeğer olmayan öntest-sontest kontrol gruplu yarı deneysel desen kullanılmıştır. Çalışma grubu, 2017–2018 eğitim-öğretim yılında Türkiye'de bir fen lisesinde öğrenim gören 59 öğrenciden oluşmaktadır. Deney grubunda 29, kontrol grubunda ise 30 öğrenci yer almıştır.

Veri Toplama Araçları: Akademik başarı puanları, öğrencilerin e-okul sisteminde yer alan dönem sonu yazılı notlarından elde edilmiştir. Eleştirel düşünme becerileri ise Sarıgöz (2014) tarafından geliştirilen Eleştirel Düşünme Becerileri Ölçeği (EDBÖ) ile ölçülmüştür.

HTA Uygulaması: 8 hafta süren uygulamalarda her hafta dersin bir saatinde, öğrencilerle açık uçlu sorular ve bu sorulara ait yanlış çözümler paylaşılmıştır. Öğrencilerden bu çözümlerde hata olup olmadığını tespit etmeleri ve hatanın kaynağını analiz etmeleri istenmiştir. Uygulanan sorular, 9. sınıf matematik öğretim programı kazanımları dikkate alınarak hazırlanmıştır.

HTA Milli Eğitim Bakanlığı'nın Fen Liseleri için belirlediği 9. sınıf matematik öğretim programındaki kazanımlar dikkate alınarak geliştirilmiş açık uçlu sorular ve bu sorulara kasıtlı olarak oluşturulmuş hatalı çözümlerden oluşmaktadır. Etkinliklerin tasarımında, öğrencilerin yaygın kavram yanılgılarını yansıtacak şekilde hatalı örnekler oluşturulması hedeflenmiş ve Melis'in (2005) bu yöndeki önerileri temel alınmıştır. Bu amaçla, 9. sınıf öğrencilerinin karşılaştığı kavramsal zorluklar ve hata türlerine ilişkin deneysel çalışmalardan yararlanılmıştır.

Ayrıca, yalnızca öğrenci yanlışlarına değil, uzman görüşleriyle oluşturulan hatalara da yer verebilmek amacıyla daha önce literatürde yer alan HTE örneklerinden (Gedik, 2014; Gedik ve ark., 2017; Özkaya, 2015; Özkaya, Konyalıoğlu & Gedik, 2013; Shabanifar, 2014) ve alan uzmanlarının değerlendirmelerinden faydalanılmıştır. Hazırlanan soru ve çözümler, iki matematik eğitimi akademisyeni ve deneyimli bir lise matematik öğretmeni tarafından içerik geçerliği ve anlaşılırlık açısından değerlendirilmiş, gelen geri bildirimler doğrultusunda gerekli düzenlemeler yapılmıştır.

HTA uygulamaları, sekiz hafta boyunca haftada bir ders saati süresince yürütülmüş ve her hafta en az iki açık uçlu soru ile bu sorulara ait etiketlenmemiş hatalı çözümler akıllı tahta üzerinden öğrencilere sunulmuştur. Öğrencilere her bir etkinlikte "Bu çözümde hata var mı? Varsa hatanın kaynağı nedir?" soruları yöneltilmiş, ardından sınıf içinde tartışmalar gerçekleştirilmiştir.

Verilerin Analizi: Akademik başarı ve eleştirel düşünme puanlarının karşılaştırılmasında bağımlı ve bağımsız örneklemler için t-testi analizleri SPSS 22.0 programı kullanılarak yapılmıştır.

Bulgular

Akademik Başarı: Uygulama öncesinde deney ve kontrol gruplarının başarı puanları arasında anlamlı bir fark bulunmazken, uygulama sonrasında deney grubunun puanları anlamlı düzeyde artmış, kontrol grubunda ise düşüş yaşanmıştır. Bu durum, HTA' nın öğrencilerin

kavramsal düzeyde daha derin ve kalıcı öğrenme gerçekleştirmelerini sağladığını göstermektedir.

Eleştirel Düşünme Becerileri: Deney grubunun sontest eleştirel düşünme puanlarında artış gözlenmiş, bu artış istatistiksel olarak anlamlı olmamakla birlikte kontrol grubunun sontest puanlarında anlamlı bir düşüş saptanmıştır. Gruplar arası karşılaştırmada ise sontest puanları deney grubu lehine anlamlı fark göstermiştir. Bu bulgu, HTA' nın öğrencilerin hataları analiz etme, neden sonuç ilişkisi kurma ve sorgulama gibi üst düzey düşünme becerilerini geliştirdiğini ortaya koymaktadır.

Tartışma ve Sonuç

Araştırma bulguları, HTA' nın öğrencilerin hem akademik başarılarını hem de eleştirel düşünme becerilerini geliştirmede etkili bir yöntem olduğunu göstermektedir. Deney grubundaki öğrencilerin, yalnızca doğru cevaba ulaşmak yerine hatayı analiz ederek kavramsal anlayışlarını güçlendirdikleri ve problem çözme stratejilerini çeşitlendirdikleri görülmüştür. Bu sonuçlar, Brodie (2014), Heinze & Reiss (2007) ve Borasi (1994) gibi araştırmacıların HTA' nın öğrenme sürecindeki rolüne dair bulgularıyla da örtüşmektedir.

Öğrencilerin hatalara yönelik tutumlarının değişmesi, onları daha sorgulayıcı ve eleştirel bireyler haline getirmiştir. Bu da HTA' nın yalnızca akademik gelişim değil, aynı zamanda bilişsel ve duyuşsal gelişim açısından da önemli katkılar sunduğunu göstermektedir.

Öneriler

Öğretmen Eğitimi: Matematik öğretmenlerinin HTA konusunda hizmet içi eğitim alarak, hataların öğrenme sürecine entegre edilebileceği konusunda bilgi ve beceri kazanmaları sağlanmalıdır.

Müfredat Entegrasyonu: Özellikle öğrencilerin sıklıkla hata yaptığı konulara yönelik yapılandırılmış HTA örnekleri, resmi matematik müfredatına dahil edilmelidir.

Farklı Branşlarda Uygulama: HTA yaklaşımı yalnızca matematik değil, fen bilimleri, dil öğretimi gibi diğer derslerde de uygulanarak çok disiplinli bir öğrenme ortamı oluşturulabilir.

Farklı Yaş Gruplarıyla Çalışmalar: HTA'nın ortaokul ve ilkokul düzeyinde de uygulanabilirliği araştırılarak daha geniş yaş gruplarında etkisi incelenmelidir.