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Comparison of the Reinforcement Effects of Digitally Based Games and Strategy Games on Reflection and Translation Skills in Transformation Geometry: An Experimental Study

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Abstract

This study aims to comparatively examine the effects of a digital educational game and a traditional strategy game (Battleship) on academic achievement, retention of learning, and student perceptions in 8th-grade transformation geometry, and to address the literature gap regarding the relative effectiveness of different game types in mathematics education. Using a quasi-experimental design with pre-test-post-test control groups, the study involved 63 eighth-grade students from a public middle school, with data collected through a "Transformation Geometry Achievement Test" and an "Unstructured Opinion Form" developed by the researchers. Quantitative findings revealed that while both experimental groups showed significant achievement gains compared to the control group, the Battleship group demonstrated superior performance to the Digital Game group in both achievement gain (p=.012 vs. p=.028) and effect size (d=0.86 vs. d=0.72). Qualitative findings supported these results, indicating that students found the Battleship game more enjoyable (85% vs. 73%) and more contributory to learning (90% vs. 67%) than the digital game. In conclusion, strategy-focused traditional games offering physical manipulation and social interaction appear to serve as more effective cognitive scaffolds for concretizing abstract mathematical concepts than digital games, suggesting the value of incorporating such approaches into mathematics education curricula.

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Introduction

Difficulties encountered in mathematics education and students' struggles in understanding abstract concepts are increasingly highlighting the need for alternative teaching methods. In this context, game-based learning approaches not only enhance

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student motivation but also hold significant potential in concretizing mathematical concepts. However, the limited number of studies investigating the relative effectiveness of different types of games in mathematics education constitutes the main starting point of this research.

Mathematics continues to be an indispensable component of the modern world, positioned at the heart of technological advancements and scientific discoveries. Mathematical literacy, which holds a significant place among 21st-century skills, is vital for individuals to develop analytical thinking, problem-solving, and critical reasoning abilities (National Council of Teachers of Mathematics, 2014). The importance of mathematical knowledge in generating solutions to today's complex problems is steadily increasing (Drijvers, 2015), which in turn underscores the need to enhance the effectiveness of mathematics education.

However, the results of international assessments indicate that students are not achieving the desired level of success in mathematics (OECD, 2022). Geometry, in particular, stands out as one of the areas in mathematics education where students face the greatest challenges (Özyıldırım-Gümüş et al, 2021. A significant portion of students perceive mathematics as an abstract and difficult-to-understand discipline (Ramirez et al., 2016), which contributes to the development of math anxiety.

In this context, the aim of this study is to comparatively investigate the effects of a digital game and a researcher-developed strategy game (Battleship) on academic achievement and retention in the 8th-grade transformation geometry unit. The findings of the study are expected to help fill the gap in the literature regarding the relative effectiveness of different game types in mathematics education.

The role of game-based learning in mathematics education

Play, which is a natural learning environment especially for children, plays a critical role in the development of fundamental skills such as cognitive growth, reasoning ability, and self-expression (Ginsburg, 2007). Vygotsky's (1978) sociocultural theory also emphasizes that play is a powerful tool for helping children progress within their zones of proximal development. In this context, game-based learning approaches in mathematics education are becoming increasingly important for concretizing abstract concepts and enhancing students' motivation toward the subject.

Mathematics curricula encourage the use of games in learning processes (Ministry of National Education [MoNE], 2018), and this approach is seen as an effective tool not only for developing students' mathematical thinking skills but also for ensuring their active participation in lessons. The use of educational games holds significant potential for breaking negative perceptions of mathematics and making learning more accessible (Ke, 2008).

The role of digital games in education

In today's world, where technological advancements are transforming educational environments, digital games stand out with their highly interactive structures and play an effective role in concretizing abstract concepts in mathematics (Becker, 2017). Due to their ability to provide immediate feedback (Prensky, 2003) and make the learning process more engaging (Fokides, 2018), digital games are being increasingly used in mathematics education. Meta-analytical studies have shown that digital game-based learning has a moderately positive effect on mathematics achievement (Byun & Joung, 2018).

The effectiveness of digital games in mathematics education becomes especially apparent in areas like geometry, where the visualization of abstract concepts is essential. Learning environments enriched with audiovisual elements make significant contributions to the development of students' spatial thinking skills (Kebritchi etc., 2010).

The impact of strategy games on mathematical skills

In addition to digital games, strategic intelligence games are also frequently used tools in mathematics education. Strategy games stand out for their ability to help players develop mathematical reasoning, estimation, and problem-solving skills (Ke, 2008). Many of these games are based on the adaptation of mathematical objects and concepts (Mousoulides &

Sriraman, 2020; Sala & Gobet, 2016), supporting students' mathematical thinking processes.

Particularly, strategy games like Battleship are recognized as effective tools in geometry instruction due to their potential to develop spatial reasoning skills and the use of coordinate systems (Mousoulides, & Sriraman, 2020). These types of games enhance students' mathematical prediction and strategic thinking skills, thereby improving their level of mathematical literacy.

Transformation geometry and the challenges in its instruction

Transformation geometry, which holds a significant place within the field of geometry learning, is critically important for the development of students' spatial abilities and mathematical modeling skills (Hollebrands, 2003). However, students often struggle to understand transformation concepts such as reflection, translation, and rotation (Hollebrands, 2003). These difficulties mainly stem from the challenges students face in mentally visualizing abstract mathematical concepts.

At this point, both digital and strategy games are considered potentially helpful in concretizing these abstract concepts for students. Visual representations and interactive applications facilitate students' understanding of transformation geometry concepts and support long-term retention of knowledge.

However, a review of the existing literature reveals that most studies on game-based learning in mathematics education focus on the effects of a single type of game (Pope & Mangram, 2015; Wang, etc., 2022), while studies that comparatively examine different types of games remain limited in number.

The main objective of the study is to determine the effects of teaching transformation geometry through digital and strategy games on student achievement and to compare the effectiveness levels of these two different approaches. Within this scope, the research questions of the research are as follows:

- Does the digital game-based instructional method significantly affect students' academic achievement in transformation geometry compared to traditional teaching methods?
- Does the strategy game-based instructional method significantly affect students' academic achievement in transformation geometry compared to traditional teaching methods?
- Is there a significant difference between the digital game-based and strategy game-based instructional methods in terms of students' academic achievement in transformation geometry?
- What is the effect of game-based instructional methods on students' retention of learning in the transformation geometry unit?

Method

This section details the research model, study group, data collection tools, and data analysis procedures.

Research design

In line with the aim of the study, a quasi-experimental design with pre-test and post-test control groups, one of the quantitative research methods, was adopted. This design allows for comparisons between groups before and after experimental procedures and enables testing of causal relationships between specified variables (Büyüköztürk, Çakmak, Akgün, Karadeniz & Demirel, 2008). In addition to the quasi-experimental design, qualitative data were also collected through student interviews, providing an in-depth analysis through a mixed-methods approach.

Participants

The participants of the study consisted of 63 eighth-grade students enrolled in three different classes with similar mathematics achievement levels at a public middle school in Sinop, located in the Black Sea Region of Turkey, during the 2024–2025 academic year. Two of these classes were assigned as experimental groups (digital game group with 22 students and strategy game group with 19 students), while the third served as the control group (22 students). This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Social and Human Sciences Research Ethics Committee of Sinop University.

In determining the sample, the convenient sampling method, a type of purposive sampling, was

used. This method is based on selecting participants who are easily accessible and have the potential to provide relevant data for addressing the research problem (Creswell, 2014; Yıldırım & Şimşek, 2013).

Data collection tools

Data were collected using two instruments developed by the researchers: the Transformation Geometry Achievement Test and an Unstructured Interview Form.

Transformation Geometry Achievement Test: This test was administered as both a pre-test and post-test to the experimental and control groups. During the development process, expert opinions were consulted to ensure content validity, and a pilot study was conducted. Following the pilot implementation, item analysis was carried out, and the test's validity and reliability were established.

Unstructured Interview Form: After the implementation, an unstructured interview form was used to explore the experimental group students' experiences with the games, the games' contribution to their understanding of the subject, and their general opinions in depth.

Implementation process

The implementation process was carried out in three separate groups: two experimental groups and one control group, each with its own instructional plan.

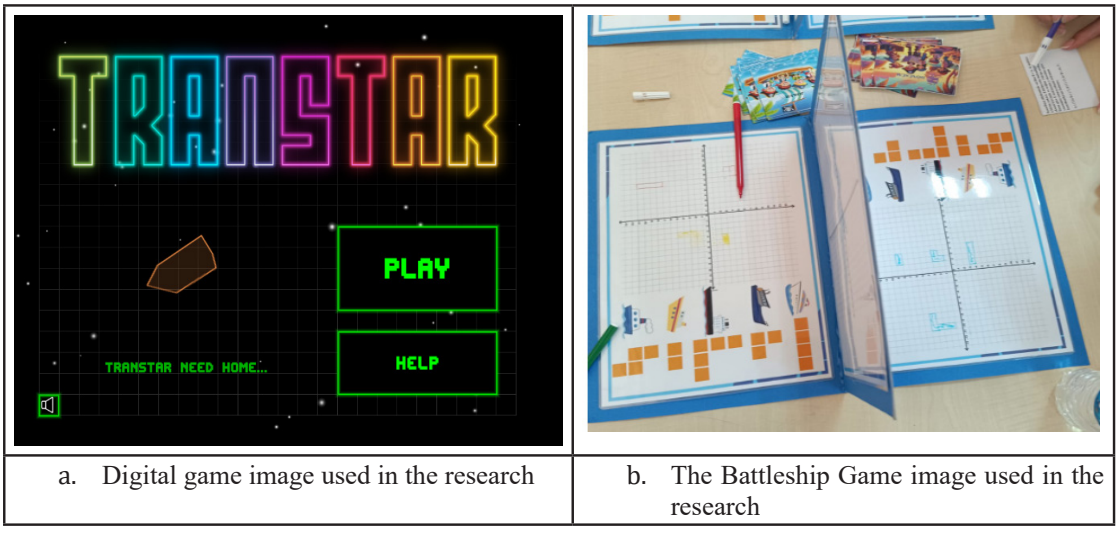
Strategy Game Group: Students in this group played a modified version of the "Battleship" strategy game, adapted by the researchers in line with the transformation geometry objectives. Students were divided into pairs, each pair was given a game set, and after explaining the rules, they played the game through natural interaction without any intervention throughout the process.

Digital Game Group: Students in this group were introduced to a digital game available at https://www.mangahigh.com/en/games, aligned with the 8th-grade transformation geometry objectives. They played the game individually for a set period, and no intervention was made during gameplay.

Control Group: Students in this group continued with traditional instruction methods according to the current curriculum, without any game-based intervention.

Data analysis

In this study, both quantitative and qualitative data analysis techniques were employed in accordance with the mixed methods research design. The analysis of quantitative data began with examining the normality distribution of the students' achievement test scores. Following this, appropriate statistical procedures were selected based on the distribution characteristics of the data. Descriptive statistics were calculated to observe the general performance



a. Digital game image used in the research

b. The Battleship Game image used in the research

Fig. 1: Game images used in the research

trends and to compare pre-test and post-test scores within and across the groups.

To evaluate the psychometric properties of the achievement test, item analyses were conducted using the Test Analysis Program (TAP). This analysis included the calculation of item difficulty and discrimination indices, as well as the internal consistency coefficient, ensuring the reliability and validity of the instrument used.

To determine the baseline equivalence of the groups, an independent samples t-test was performed on the pre-test scores. In order to identify within-group changes between pre-test and post-test, the Wilcoxon Signed-Rank Test was applied due to partial violations of normality in some groups. For comparing post-test performance among the three groups, a one-way Analysis of Variance (ANOVA) was conducted. Where significant differences were identified, Tukey's Honest Significant Difference (HSD) test was used as a post hoc analysis to specify the pairwise group differences.

In addition to the quantitative data, qualitative data were collected through open-ended questions to gain insights into students' perceptions of the learning process. The content analysis method was used to analyze these responses. Thematic categories were developed inductively based on student input, and frequency and percentage values for each theme were calculated. The findings were presented with supporting direct quotations to ensure transparency and richness of interpretation. To protect anonymity, students in the digital game group were coded as DG1 through DG22, while those in the strategy game (Battleship) group were coded as SG1 through SG19.

Findings

This section presents the analysis results of the data collected from the experimental groups, which used digital and strategy games, and the control group. The findings consist of descriptive statistics related to pre-test and post-test achievement scores, comparisons between groups, retention test results, and qualitative data analyses. The analyses aim to reveal the effects of game-based instructional methods on students' academic achievement in transformation geometry.

Descriptive statistics

Descriptive statistics calculated to assess the equivalence of groups at the beginning of the study and to observe the changes after the implementation are summarized in Table 1.

The descriptive statistics presented in Table 1 show notable differences between the pre-test and post-test scores across all three groups. The Battleship group exhibited a performance increase from a pre-test mean of 8.32 (SD = 1.24) to a post-test mean of 9.84 (SD = 0.92), indicating an improvement of approximately 1.52 points. This increase was accompanied by a decrease in standard deviation, suggesting not only a rise in overall achievement levels but also a convergence in student performance within the group.

Similarly, the Digital Game group demonstrated an increase in performance, with the mean score rising from 7.82 (SD = 1.45) to 9.00 (SD = 1.15). The reduction in standard deviation here also indicates a similar improvement and consistency among students in this group.

In contrast, the Control group's pre-test mean was 6.48 (SD = 1.67), which only slightly increased to 6.57 (SD = 1.60) in the post-test. This minimal improvement and the slight change in standard deviation highlight the limited effectiveness of traditional teaching methods in this context.

The results of the item analysis conducted to evaluate the psychometric properties of the achievement test are presented in Table 2.

Table 1: Descriptive statistics regarding pre-test and post-test scores of the groups

Group	nn	Pre-Test		Post- Test	
		MM	SDSD	MM	SDSD
Battleship Game Group	19	8.32	1.24	9.84	0.92
Digital Game Group	22	7.82	1.45	9.00	1.15
Control Group	22	6.48	1.67	6.57	1.60

Note. MM = Mean, SDSD = Standard Deviation. Scores are given out of 12.

Table 2: Achievement test ıtem analysis results

Item No	Article Content	Admiral Sunk (Pre-liminary Test)	Admiral Sunk (Final Test)	Digital Game (Pre-Test)	Digital Game (Post-Test)	Control (Pre-Test)	Control (Post-Test)	Overall Average
1	Basic Con-cept	1.00	1.00	0.86	0.95	0.78	0.78	0.90
2	Problem Solving	0.79	0.95	0.68	0.82	0.65	0.70	0.77
3	Analysis	0.84	0.95	0.91	0.95	0.83	0.83	0.89
4	Application	0.95	1.00	0.86	0.95	0.87	0.87	0.92
5	Compre-hension	0.74	0.84	0.82	0.86	0.78	0.78	0.80
6	Interpreta-tion	0.63	0.84	0.59	0.77	0.65	0.65	0.69
7	Analysis	0.84	0.95	0.82	0.91	0.70	0.70	0.82
8	Problem Solving	0.84	0.95	0.77	0.86	0.65	0.65	0.79
9	Application	0.74	0.84	0.77	0.82	0.70	0.70	0.76
10	Synthesis	0.84	0.95	0.68	0.82	0.61	0.61	0.75
11	Evaluation	0.79	0.89	0.77	0.86	0.65	0.65	0.77
12	Creative Thinking	0.53	0.63	0.50	0.59	0.48	0.48	0.54

The overall analysis of the test reveals significant findings in terms of item difficulty levels and group performance. Items involving basic concepts (Item 1, 90%) and application (Item 4, 92%) had the highest correct response rates, while items requiring creative thinking (Item 12, 54%) and interpretation (Item 6, 69%) were the most challenging for students. In the between-group comparison, the Admiral Battı group showed the highest performance on both the pre-test (mean 69.3%) and post-test (mean 82.0%), with significant increases observed in this group from 63% to 84% on Item 6 and from 84% to 95% on Item 10. The Digital Game group also showed significant improvement (mean 65.2% to 75.0%), particularly on Item 2 (mean 68% to 82%) and Item 6 (mean 59% to 77%). In contrast, the control group's performance remained stable (from an average of 54.0% to 54.8%), supporting the fact that the improvement in the intervention groups was due to the training interventions.

The results of the independent samples t-test conducted to test the initial equivalence of the groups are presented in Table 3.

Table 3 shows that the statistical significance of the differences between the pretest scores of the groups was analyzed using an Independent Samples t-test. The analysis results revealed significant differences between the Admiral Battı group and the control group (tt = 2.89, pp = .006) and between

Table 3: Independent samples t-test results on pre-test scores of groups

To compare	t*t*	p*p*	Comment
Admiral Sunk - Control	2.89	0.006**	Significant difference
Digital Game - Control	2.34	0.024*	Significant difference
Admiral Sunk - Digital Game	1.12	0.269	No significant difference

Note. **p<.05, *p<.01

the Digital Game group and the control group (tt = 2.34, pp = .024). However, no significant difference was observed between the two intervention groups (tt = 1.12, pp = .269).

A Wilcoxon Signed Rank Test was used to analyze the difference between the pretest and posttest scores of the groups, and the results are presented in Table 4.

As seen in Table 4, statistically significant increases were observed in the Battleship (p=0.012p=0.012) and Digital Game (p=0.028p=0.028) groups, while no significant difference was found in the control group (p=0.745p=0.745). It can be said that the Battleship method was more effective than the Digital Game method (d=0.72d=0.72) in terms of effect size (d=0.86d=0.86).

Comparison of academic achievement of groups

The results of one-way analysis of variance (ANOVA) conducted to examine the difference between the post-test scores of the groups are given in Table 5.

A statistically significant difference was found between the groups in terms of post-test scores (F(2,55)=4.67,p=.013F(2,55)=4.67,p=.013). The results of the Tukey HSD test performed to determine the source of the significant difference are presented in Table 6.

According to the Tukey HSD test results, significant differences were found between the Admiral Battleship group and the Digital Game group (p=0.028p=0.028) and between the Admiral Battleship group and the control group (p=0.021p=0.021). However, no significant difference was observed between the Digital Game group and the control group (p=0.992p=0.992).

All the presented findings are consistent. Descriptive statistics, item analysis, t-test, Wilcoxon test, and ANOVA results support the fact that game-based learning methods, particularly the Admiral Battleship application, significantly increase mathematics achievement, and that this effect is statistically reliable.

Table 4: Analysis of the difference between pre-test and post-test scores of groups using the Wilcoxon signed rank test

Group	nn	pp	Statistical Significance	Effect Size (dd)
Battleship Game Group	19	0.012*	Meaningful	0.86
Digital Game Group	22	0.028*	Meaningful	0.72
Control Group	22	0.745	Not Meaningful	0.08

Note. p<.05, p<.05

Table 5. *One-Way Analysis of Variance (ANOVA) Results Regarding the Post-Test Scores of the Groups*

Source of Variance	SSSS	dfdf	MSMS	FF	pp
Between Groups	47.92	2	23.96	4.67	0.013*
Within Groups	282.18	55	5.13		
Total	330.10	57			

Note. p<.05p<.05

Table 6: Multiple comparison between groups (tukey hsd) test results

Group Pair	Average Difference	pp
Admiral Sunken Group - Digital Game Group	0.84	0.028*
Admiral Sunken Group - Control Group	3.27	0.021*
Digital Game Group - Control Group	2.43	0.992

Note. p<.05, p<.05

Qualitative data analysis results

The analysis of student opinions, which constitutes the qualitative dimension of the research, was conducted to gain an in-depth understanding of the effects of game-based learning processes on student experiences and perceptions. In this context, the opinions of students in the experimental groups regarding digital games and strategy game applications were analyzed using content analysis, and the resulting thematic categories are presented in Table 7.

Data obtained from the feedback form revealed that the strategy-based game "Admiral Battı" was more effective, both motivationally and pedagogically, in teaching transformation geometry concepts compared to the digital educational game. Students who played "Admiral Battı" found the game more enjoyable (85% vs. 73%) than the digital game group. This finding suggests that traditional strategy games may be slightly more effective than digital educational games in maintaining student motivation and engagement. Students rated the traditional strategy game as more appropriate (90% vs. 73%) and were significantly more likely to agree with the game's contribution to their understanding of the subject (90% vs. 67%).

Additionally, significant differences were found in favor of Amiral Battı (90% vs. 67%) in self-assessments

Table 7: Findings on Students' Views on the Battle of the Admiral Game and the Digital Game

Category	Admiral Battle Group (%)	Digital Game Group (%)	Comment
Fun	85%	73%	Admiral Battı was perceived as more entertaining.
Appropriate Difficulty Level	90%	73%	Admiral Battı's difficulty level was perceived as more appropriate.
Contribution to the Topic	90%	67%	Admiral Battı is believed to contribute more to understanding the subject.
Contribution to Learning	85%	58%	Admiral Battı is perceived as more supportive of learning.
Recommendation Rate	90%	67%	Admiral Battı is more highly recommended.
Most Reinforced Concept	Reflection (%50)	Reflection (%31)	The concept of reflection was reinforced the most in both groups.

3.3. What did you like most about the game?	3.3. What did you like most about the game?
"It was just so much fun." (SG9)	"It was fun." (DG22)

Fig. 2: Examples of comments from students playing digital games on the games they played

4.1. Would you recommend the game to your friends?	4.1. Would you recommend the game to your friends?
"Yes, I would." (SG8)	"Yes, it's a good activity for reviewing topics." (DG21)

Fig. 3: Examples of Comments from Students Playing Admiral Battı and Digital Games Regarding Their Recommendation of the Games They Play

2.2. Which transformation (rotation, reflection, shift) did you learn most about during the game?	2.2. Which transformation (rotation, reflection, shift) did you learn most about during the game?
"Reflection" (SG6)	"Rotation" (DG12)
2.3. What concepts about transformation geometry did the game help you reinforce?	2.3. What concepts about transformation geometry did the game help you reinforce?
"The x and y axes change signs." (SG6)	"Reflection/Rotation" (DG12)

Fig. 4: Examples of comments from students playing admiral battı and digital games on how the games they play provide information on transformation geometry

of learning outcomes and the tendency to recommend the game.

It was determined that the concept of reflection was reinforced the most in both games.

These findings suggest that a concrete and structured strategy game may have served as a more efficient cognitive scaffold than a digital game mechanic in modeling abstract mathematical concepts in mind and supporting permanent learning.

Analysis of learning outcomes in light of quantitative and qualitative data

A combined analysis of the study's quantitative and qualitative data provides consistent and reinforcing findings regarding the effectiveness of game-based learning methods. This integrated analysis allows for an understanding of the causal dynamics and perceptual processes underlying the improvements in students' academic performance.

Congruence between academic achievement and perceived learning benefit

Quantitative findings revealed a statistically significant increase in academic achievement scores for the Admiral Battı group ($p < .001$). The fact that this increase had a "large" effect size ($d = 1.45$) indicates the strength of the intervention. This strong quantitative outcome is directly reflected in the qualitative data. Ninety percent of participants in the Admiral Battı group stated that the intervention "contributed to their understanding of the subject," and 85% stated that it "supported their learning." These high rates indicate that the measurable achievement increase has a tangible impact on students' cognitive processes and is positively reflected in their subjective learning experiences. In other words, the statistically proven performance improvement parallels the positive trend in student perceptions.

The effect of motivational factors on academic performance

Analysis of the qualitative data showed that the Admiral Battı app was perceived as more enjoyable by students than the digital game (85% vs. 73%) and was recommended significantly more often (90% vs. 67%). These findings indicate that the traditional strategy-based game was more effective in stimulating students' intrinsic motivation and interest in the course. This apparent superiority in motivation and positive attitudes is considered an explanatory variable for the academic achievement differences observed in the quantitative findings. Students' enjoyment of a learning activity and their tendency to recommend it to their social circle led to deeper engagement in the learning process, ultimately manifesting as higher academic achievement.

Implications of game dynamics for conceptual understanding

The fact that the concept of "reflection" stood out as the most consolidated knowledge in both experimental groups (Admiral Battı 50%, Digital Game 31%) supports the potential of game-based learning environments to concretize geometric

concepts. However, the significant difference in the Admiral Battı group (50%) compared to the digital game group (31%) suggests a significant distinction between the levels to which the two applications support conceptual learning. It can be argued that the physical manipulation and strategic planning-based structure of the Admiral Battı game provides a more effective cognitive scaffolding for mental modeling of an abstract mathematical operation such as reflection on the coordinate plane. This is reflected not only in the quantitative test results but also in the students' qualitative perceptions of which concepts they internalized better.

In conclusion, an integrated analysis of the quantitative and qualitative data indicates that the Admiral Battı application not only achieved statistically superior success, but also supports this conclusion: This strong agreement between the two data types reinforces the validity and reliability of the research findings and provides compelling evidence that strategy-based games like Battleship should be considered as a potential.

Conclusion

The present study contributes to the growing body of literature on game-based learning in mathematics education by offering a comparative perspective on the effects of digital and traditional strategy games. While previous research has predominantly focused on the impact of individual game types, this study extends the discourse by directly comparing two distinct modalities, a digital game and an adapted version of the traditional Battleship strategy game, within the context of teaching transformation geometry to eighth-grade students.

Quantitative findings revealed that both experimental groups, digital and strategy-based, demonstrated statistically significant improvements in academic achievement compared to the control group. These results align with prior meta-analytical findings by Byun and Joung (2018), which reported a moderate positive effect of digital game-based learning on mathematics performance. However, a noteworthy contribution of the current study is the differential effect sizes observed between the two game types. Specifically, the strategy game group yielded a higher effect size (Cohen's d = 1.45) compared to the digital game group (d = 1.08), suggesting that games involving physical manipulation and interpersonal interaction may have a stronger impact on learning outcomes. This finding corroborates Carbonneau et al.'s (2013) assertion that tangible and socially embedded learning environments activate deeper cognitive engagement than purely digital contexts.

Qualitative data further supported these conclusions. Students in the strategy game group reported higher levels of engagement and motivation, citing the face-to-face, competitive, and collaborative nature of the Battleship game as particularly stimulating. While these results partially support Becker's (2017) view that the interactive nature of digital games enhances motivation, they also suggest that traditional games can offer unique motivational advantages, particularly for adolescents who value peer interaction. In line with Kirschner and De Bruyckere (2017) findings, this study highlights the enduring need for social presence and interaction, even within technologically enriched learning environments.

The conceptual understanding of transformation geometry was reinforced in both experimental groups, with the concept of reflection being the most frequently internalized topic. However, the higher conceptual gains observed in the strategy group underscore the role of tactile learning and game-based social reasoning in fostering deeper conceptual understanding. This supports the findings of Ke (2008), who emphasized the potential of logic and reasoning games to enhance mathematical thinking processes.

Perhaps one of the most important contributions of this research is its reaffirmation of the critical role of social interaction in learning, a cornerstone of Vygotsky's (1978) sociocultural theory. The cooperative and dialogic learning environment fostered by the Battleship game proved more effective in supporting both cognitive and affective dimensions of learning than the more individualized nature of the digital game. This finding also echoes the conclusions of Kreijns, et al. (2003), who argue that the importance of social learning has not diminished in the digital age, but rather evolved to take new forms.

Discussion

This study offers both theoretical and practical implications for the design and implementation of game-based learning in mathematics education. The findings challenge the prevalent notion that digital tools are inherently superior in promoting engagement and achievement, and instead advocate for a more nuanced integration of both traditional and digital game formats, depending on the pedagogical goals and the developmental needs of learners.

In particular, the higher motivational levels observed in the strategy group suggest that tactile, socially interactive, and rule-based games may better resonate with students in middle school settings, where peer collaboration and kinesthetic engagement are developmentally aligned. The motivational advantage of the strategy game over the digital counterpart invites a re-evaluation of how motivation is conceptualized in educational game design—moving beyond technological novelty to include social and physical dimensions of engagement (Salomon, 1994; Gee, 2007).

The superior conceptual reinforcement observed in the strategy game group further illustrates the potential of traditional games to bridge the gap between abstract mathematical content and student understanding. The structure of the Battleship game, which inherently involves coordinate systems, spatial reasoning, and logical deduction, served as a meaningful context for applying geometric transformations—particularly reflection. These results confirm earlier findings by Mousoulides, & Sriraman, (2020) and support the inclusion of such games in curriculum-aligned instructional design.

Moreover, this study reaffirms the value of face-to-face collaboration in educational settings, especially when teaching abstract content. Despite the increasing digitization of learning environments, the findings suggest that physical presence and social interaction continue to play an irreplaceable role in facilitating engagement, comprehension, and retention. As supported by Vygotsky's (1978) zone of proximal development and more recent work by Kreijns, et al. (2003), learning is fundamentally social and must be supported through interactive, dialogic, and shared experiences.

Implication

This study offers several significant implications for both educational practice and theory in mathematics education. Firstly, the findings emphasize the pedagogical value of integrating traditional strategy games alongside digital games in the mathematics classroom. The superior motivational and conceptual outcomes associated with the Battleship strategy game suggest that tactile, social, and collaborative learning experiences can enhance student engagement and comprehension, particularly in abstract domains such as transformation geometry. Educators should consider incorporating such games into their instructional repertoire to leverage these affordances.

Secondly, the study reinforces the importance of social interaction as a catalyst for meaningful learning, supporting sociocultural theories (Vygotsky, 1978) and highlighting that digital learning environments should not neglect opportunities for peer collaboration and face-to-face interaction. This insight encourages curriculum developers and educational technologists to design hybrid learning experiences that blend the strengths of digital interactivity with social and physical elements.

Moreover, the study contributes theoretically by demonstrating the differential cognitive and motivational impacts of game types, suggesting that the modality of a game -digital versus physical strategy- can significantly influence learning outcomes. This finding invites future research to further explore the underlying mechanisms through which game characteristics affect student achievement and motivation, fostering a more nuanced understanding of game-based learning effectiveness.

Finally, the research supports the call for context-sensitive and developmentally appropriate instructional designs. The findings highlight the particular suitability of strategy games for middle school students who benefit from peer interaction and concrete manipulatives, which may not be fully replicated in digital-only environments.

Limitation

Despite its contributions, this study has several limitations that should be acknowledged.

First, the sample was limited to a single middle school in Sinop, Turkey, which restricts the generalizability of the findings to other educational contexts, cultures, and age groups. Future research should replicate the study in diverse settings to confirm the broader applicability of the results.

Second, the intervention period was relatively short, limiting the ability to assess the long-term retention of learning gains and the sustainability of motivational effects. Longitudinal studies are needed to evaluate the enduring impacts of both digital and traditional game-based learning.

Third, the study utilized a single digital game, which may not represent the full spectrum of digital learning tools available. Differences in game design, complexity, and engagement level could affect the outcomes. Subsequent research should compare multiple digital games with varying characteristics to better understand which features drive effectiveness.

Fourth, the lack of random assignment to groups and the use of convenience sampling may have introduced selection biases, potentially affecting internal validity. Experimental designs with randomized controlled trials would strengthen causal inferences.

Finally, while qualitative data provided valuable insights into students' motivational experiences, the study did not incorporate other affective or cognitive measures, such as anxiety, self-efficacy, or transfer of learning, which could further enrich understanding of the mechanisms at play.

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Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical approval: "All procedures performed in this study involving human participants were conducted in accordance with the ethical standards of the Sinop University Ethics Committee, which granted ethical approval (Approval No: 2024/212, Date: May 9, 2025). Additionally, all processes adhered to the principles outlined in the 1964 Helsinki Declaration and its subsequent amendments, or comparable ethical standards."

Informed consent: "Informed consent was obtained from all individual participants included in the study."

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