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The Effect of Dynamic Geometry Software-Based Interactive Media with the RME Approach in Improving Critical Thinking on the Rotation Topic

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Abstract: The Effect of Interactive Media Based on Dynamic Geometry Software with the RME Approach on Improving Critical Thinking in Rotation Material**. Objectives:** The goal of this research is to examine the effect of using interactive media on Dynamic Geometry Software (DGS), like GeoGebra, along with the Realistic Mathematics Education (RME) technique in improving students' critical thinking on the topic of rotation in geometry. **Methods:** The study used both a quantitative approach and a quasi-experimental approach. There were 38 students from SMA Negeri 1 Olahraga Sidoarjo in East Java who took part in this study. The experimental class and the control class consist of 19 students each. The experimental group learned with GeoGebra-based interactive media and the RME method, while the control group learned more traditionally without technology and the RME method. A set of validated test questions was administered before and after the intervention to measure students' critical thinking skills. **Results:** There was a significant difference between the two groups' critical thinking skills. Students in the experimental class were much better at understanding, evaluating, and thinking about geometric rotation problems than students in the control class. Combining GeoGebra and RME helped students understand how rotation works in real life and made them more interested, active, and better at understanding, exploring, and using it in a meaningful way. **Conclusion:** The RME method and GeoGebra helped students think critically about geometry, especially rotation. These results support the idea that using technology in a way that makes learning mathematics more meaningful, like RME, can help students think more deeply. Teachers should think about using these kinds of strategies to help their students learn mathematics better.

Keywords: critical thinking, geogebra, quasi-experimental, RME, rotation.

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INTRODUCTION

Critical thinking is a methodical approach to thinking that involves identifying, analyzing, and evaluating the problem, and reflecting on the answer when solving arithmetic problems (Álvarez-Huerta et al., 2022; Dolapcioglu & Doðanay, 2022). In the twenty-first century, one needs to be able to think critically in order to study arithmetic. This important critical thinking skill consists of two major thinking indicators: analyzing and evaluating. These can assist pupils in figuring out how to solve problems (Rahayu, 2024). There are many benefits to learning arithmetic through critical thinking. For example, it helps you establish logical and systematic ways of thinking, gradually get better at solving problems, and become an expert in ideas (Sánchez Noroño et al., 2020). Additionally, critical thinking helps students solve problems imaginatively and make decisions based on data analysis (Iparraguirre-Villanueva et al., 2024).

Some indicators in measuring critical thinking are interpretation, analysis, inference, evaluation, explanation, and self-regulation. According to Facione (1990), this is the essential component of thinking (Putri et al., 2025). Especially in the educational field, this indicator serves as a valuable guide for the development of critical thinking abilities. This analysis indicates the ability to recognize an issue in situations where the interpretation displays the students' ability to comprehend the meaning of the information or sites. Evaluation is associated with an appraisal of the reliability of data and arguments. Inference is the capacity to logically infer conclusions from the information at hand. The ability to articulate the rationale behind their thoughts is in line with explanation. Lastly, self-regulation is the process of reflecting on and refining one's thought process. The capacity to articulate the rationale behind their thought process (Putri et al., 2025). According to this indicator, developing solid conceptual knowledge and a profound problem-solving ability are crucial for studying mathematics.

According to various sources, the most important component of education is critical thinking, especially while learning mathematics (Benyamin et al., 2021). Students who use critical thinking are better able to understand things thoroughly and analyze, evaluate, and solve issues more quickly. more effectively and fully understand things (Sk & Halder, 2020). Critical thinking is seen as crucial in arithmetic since it helps with idea understanding, problem solving, and evaluating the reasoning or logic behind an argument or solution (Dolapcioglu & Doðanay, 2022). Since it is not updated and there is no way to add new technological tools to make studying more enjoyable, mathematics is typically one of the topics that students detest the most in school, especially when it comes to the very complex geometric transformation content (Ahmad & Junaini, 2020). Several recent studies have shown that GeoGebra can change the way students and teachers view mathematics, even though Indonesian classrooms do not often use digital tools to teach geometry. For example, Romero Albaladejo & García López (2024) found that using GeoGebra in a secondary school classroom made students more independent, diligent, and precise in their mathematical thinking. In 2024, a study that used the TPACK/UTAUT framework found that teachers' knowledge of and ability to use technology in the classroom and the amount of work they have to do will affect whether or not they keep using GeoGebra (Yildiz & Arpaci, 2024). This shows how important it is to teach teachers how to use GeoGebra correctly (Susanto et al., 2023). To improve mathematics teacher and student learning through the use of this software, the International GeoGebra Institute (IGI), a non-profit organization, is a global organization that manages GeoGebra (Matsha, 2025). Rotation in geometric transformation is one of the most challenging concepts for students. Rotation is rigid to picture or even see in real life because it means moving something around a fixed point without changing its size or shape (Rahayu, 2024). Due to inadequate conceptual understanding of the concept of rotation, this has led to misunderstandings among students learning the basic concepts of rotation, such as definition, centre, angle, and its differences from other transformations, such as translation and reflection. Differences with other transformations, such as reflection and translation (Hardiyanto et al., 2024; Romero Albaladejo & García López, 2024). The limited availability of interactive learning resources, such as GeoGebra, can hinder students' understanding of geometric concepts, especially rotation (Yuan et al., 2023). According to Hardiyanto et al. (2024), interactive media can make students more interested, give them instant feedback, and help them understand concepts in depth. The study suggests that schools should ensure they have enough technology and create curriculum materials that are useful for using interactive software. Schools should ensure they have enough technology and create curriculum materials that are useful for using interactive software (Yuan et al., 2023). It is also important to do a complete evaluation of how well this media works to make sure it helps students get better at mathematics (Murni et al., 2022). When students use interactive learning media, they can connect what they learn in class with what they do in the real world, which helps them understand and apply what they learn (Hardiyanto et al., 2024; Romero Albaladejo & García López, 2024).

Dynamic Geometry Software (DGS) is an important part of geometry learning because it helps students better understand fundamental concepts by allowing them to view and modify objects in real time, such as rotations, reflections, and transformations. This dynamic geometry software also supports discovery-based learning, which allows students to make conjectures, test their ideas, and prove their results interactively (Segal et al., 2021). The use of DGS, especially GeoGebra, helps students visualize and understand learning concepts, especially in rotation material, more easily and interactively (Nasrullah et al., 2025; Zhu & Xu, 2023). Most of the early studies have developed spatial and visual skills in general, but have not focused on how students think critically about arithmetic in specific learning models. This study used GeoGebra as a learning tool and linked it to the realistic mathematics education (RME) method. The aim is to see how effective GeoGebra is in helping students think critically about rotational geometry and how the RME method can help them apply this knowledge in real-life situations.

The RME method, which emphasizes the value of interconnection, is consistent with the use of GeoGebra, which enables interactive visualization (Listiawati et al., 2023). The RME and GeoGebra approaches work well together because GeoGebra allows users to see moving objects, which is in line with the concepts of context, the real world, and directed reinvention (Ramaliana et al., 2024). Recent research indicates that the use of GeoGebra in the classroom can help children better understand geometric principles and also change the way they think about these concepts (Hadi et al., 2025). Therefore, the combination of GeoGebra and the RME approach can support students' critical thinking processes. Realistic Mathematics Education (RME) is a way of teaching mathematics that focuses on how mathematics ideas relate to students' real lives and experiences (Fauzan et al., 2024). This method helps students think critically and creatively, solve problems, and understand concepts by working together, talking to each other, and interacting with each other (Putri et al., 2024). Using GeoGebra has also greatly improved students' emotional and cognitive skills, such as their ability to stay on task and be independent.

Realistic mathematics education, or RME, is regarded as an accurate method for identifying students' learning styles based on their traits (Murdiyanto et al., 2023). The main The emphasis is on meaningful comprehension rather than rote memorization of formulas, which enhances students' literacy and numeracy in an enjoyable and applicable manner (Hidayat & Suryadi, 2023; Palinussa et al., 2021). The primary focus is on meaningful understanding rather than mechanically memorizing formulas, which enhances students' literacy and numeracy in an enjoyable and practical manner (Laurens et al., 2018; Lubis et al., 2023).

When students use the RME approach to read carefully and connect what they learn with their surroundings, they will become more enthusiastic about learning and improve their mathematical literacy and numeracy skills (Fauzana et al., 2020; Yildiz & Arpaci, 2024). The use of GeoGebra is an important component of RME-based education, which promotes the development of critical thinking in students (Kusumah et al., 2020). GeoGebra itself is a software program that allows you to explore mathematical concepts, view data in new ways, analyze information, and improve problem-solving skills (Ishartono et al., 2022; Tamam & Dasari, 2021).

A new study showed that teaching transformational geometry to children by connecting it to real life can help them think more deeply (Susandi & Widyawati, 2022). The study found that in the digital age, GeoGebra combined with the RME approach can help children learn. The RME method is superior to direct instruction in helping elementary school students think critically about math. Few studies have examined the collaborative effects of RME and DGS on students' critical thinking, particularly in understanding geometry concepts like rotation (Listyaningrum et al., 2025). This study looks at how using the combination of DGS media and RME affects students' critical thinking skills on the rotation topic. The research question is, "What effect does using DGS media with RME have on students' critical thinking when learning rotation?"

■ METHOD

This study included 38 students from SMA Negeri Olahraga in Buduran District, Sidoarjo Regency, East Java, Indonesia. There were two groups of 19 students each. The study used a two-class institution format combined with pretest-posttest assessment and experimental and control groups, where the experimental group learns through interactive media based on Geogebra and the control group uses traditional teaching methods. There were two classes of tenth-grade students in the study. One class was the experimental class, and the other was the control class.

This study used quantitative methods and a quasi-experimental design called a non-equivalent control group. Purposive sampling was used to determine the participants. The "equivalent academic level" criterion was used to choose the sample so that both classes would start the learning with the same level of aptitude. Then, each class took a pretest to assess the students' initial abilities. After that, each class received treatment. The control class will receive treatment similar to traditional learning without the aid of GeoGebra. In contrast, the experimental class will receive treatment with the aid of GeoGebra technology or dynamic geometry software. After both classes received treatment, a posttest was administered to evaluate the results.

Eighteen essay questions on this test are meant to assess students' critical thinking skills utilizing the RME method. These questions were checked before being used to ensure they are legitimate and reliable. The Pearson product-moment correlation was used to check for validity. There is a strong link between each item and the total score at a level of 0.05. The Cronbach's Alpha reliability test also gives a coefficient of 0.961, which suggests that the tool is very reliable and consistently measures ability. The pretest and posttest used an essay-based vital wondering skills check device with signs according to Facione (Putri et al., 2025). The pretest and posttest assessments include critical thinking indicators as described by Facione (Putri et al., 2025). According to Facione (1990), there are six critical thinking indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation, which are evaluated. Each of the six critical thinking skills identified by Facione is linked to the assessment instrument through one essay question related to the rotation material. Each indicator is scored on a scale of 5 to 20 using a quantitative rubric.

The research data were analyzed using descriptive statistical methods to summarize the findings. A Kolmogorov-Smirnov test was conducted at a 5% significance level to assess the normality of the data distribution. If the data were found to be normally distributed, a Paired

Student's t-test would be employed for analysis. Conversely, if the data did not meet the normality assumption, the Wilcoxon test (non-parametric) would be utilized. Additionally, the homogeneity of variances between the experimental and control groups' posttest scores was examined. If the data were normally distributed, an independent sample t-test would be applied; if not, the Mann-Whitney test would be used.

RESULT AND DISCUSSION

According to the study's findings, implementing dynamic geometry software, such as GeoGebra, in math classes may encourage students to think more critically, particularly when they are studying complex concepts like geometric transformations. Interactive digital tools can help students better understand concepts and make lessons more engaging for teachers and other curriculum developers. Also, teacher training programs should teach DGS-based strategies so that teachers can use them more easily in the classroom.

The study was conducted on one topic (rotation in geometry) with a small sample size. The study was also conducted in a controlled setting, so it does not work as well at other schools. Researchers might want to evaluate how DGS integration changes students' ability in different maths topics and levels of education over time. Getting teachers' thoughts and worries about these technologies might also help us figure out how to use them in a way that is environmentally friendly.

Descriptive Analysis of Students' Critical Thinking Skills

Descriptive statistical analysis in this study consists of the number of records, the maximum score, the minimum score, the average, the range, the standard deviation, and the valid values.

Table 1. Description of research data

Descriptive Statistic						
Class	**N**	**Range**	**Min**	**Max**	**Mean**	**Std. Deviation**
Experimental class pretest	19	72	0	72	13.00	17.951
Experimental class posttest	19	75	5	80	32.84	27.779
Control class pretest	19	85	0	85	27.95	22.322
Control class posttest	19	54	0	54	14.58	17.248

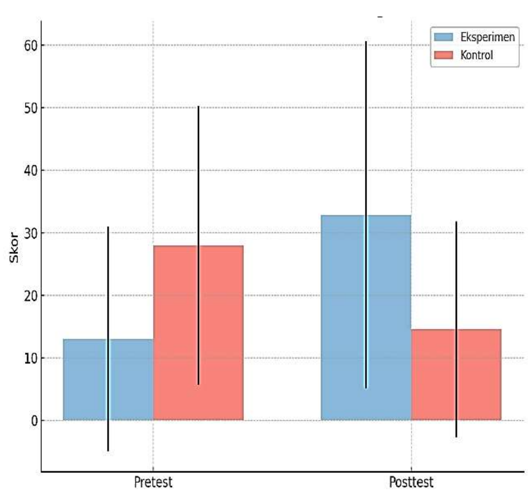

Figure 2. Bar chart of pretest and posttest mean scores with standard deviation

The average score on the pretest for the experimental class was 13.00, with a standard deviation of 17.951. The mean score of 32.84 and the standard deviation of 27.779 show that the posttest score was higher. The use of GeoGebra and Dynamic Geometry Software together in interactive media dramatically improved students' ability to think critically. The average pretest score for the control group was 27.95, with a standard deviation of 22.32. The average posttest score was 14.58, with a standard deviation of 17.24.

There could be many reasons why the control group's posttest scores are lower than the sexperiment class. Students in the control group learnt traditionally, without the use of interactive and visual learning tools. This could mean they were less motivated or interested. Fatigue during the test and distractions from external sources during the posttest session could also be contributing factors. Furthermore, the teaching method in the control class may have been less effective in helping students understand concepts or develop their critical thinking skills. This would have made it harder for them to remember and use what they learnt and made them making them reluctant to participate in the learning process. This is because students who are unable to visualize things will struggle and become confused when learning the information traditionally. The old teaching approach does not help students think critically; it makes it worse. An N-Gain calculation was then carried out to assess the treatment's efficacy in the experimental class. Table 2 below provides an overview of the N-Gain statistics:

Table 2. Description of N-Gain

Statistic	Results
Mean	15.28
Median	5.00
Standard Deviation	49.68
Minimum – Maximum	-142.86 – 80.00
Skewness	-1.512
Kurtosis	5.170
95% Confidence Interval	-8.66 – 39.22

The results reveal that the average value of N-Gain for the experiment class, determined through descriptive statistics, is 15.28, with a standard deviation of 49.68. The range of values is quite wide, with a minimum value of -142.86 and a maximum value of 80.00, for a total of 222.86. The difference between the mean and the median is indicated by the median value of 5.00, meaning that half of the data is below or above this value. For clarity, the following shows an N-Gain bar chart with error bars:

The data is left-skewed, meaning that more data is above the mean score, according to the skewness score of -1.512. The kurtosis score of 5.170, which also shows that the data has sharper peaks than a normal distribution (leptokurtic), suggests that the data may contain extreme values.

Although the mean is positive, there is significant uncertainty regarding the population mean; this may be due to the high variation in the data (as indicated by the variance value of 2467.79). The mean's 95% CI ranges from -8.66 to 39.22. These results are in line with other studies that using GeoGebra with the RME technique can help pupils think more critically (Benning et al., 2023; Susanto et al., 2023). However, the effectiveness of the intervention varied among students, with some showing negative gains and others experiencing significant improvement (e.g., gains of up to 80). This

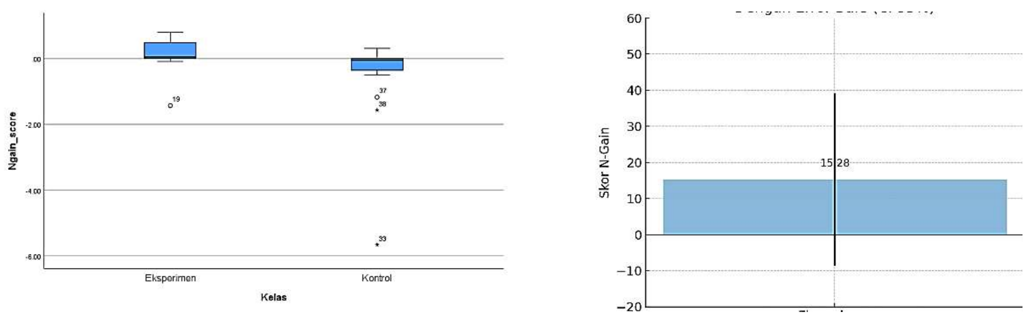

Figure 3. The experimental class's and control class's bar chart

discrepancy may be due to differences in the students' prior knowledge, learning styles, or engagement during the intervention, and it emphasises the importance of taking individual characteristics into account when implementing GeoGebra and RME more broadly.

Although its efficacy in learning is dependent on the application context, GeoGebra has been demonstrated to be beneficial. When project-based learning was combined with GeoGebra (Setyawan et al., 2024), it demonstrated an improvement in critical thinking abilities. Depending on the circumstance, GeoGebra's impact on spatial visualization changed, according to Suparman et al.'s (2024) study. Meanwhile, a study conducted in Rwanda by Ndagijimana et al. (2024) demonstrated enhanced comprehension of fundamental geometry within a sociocultural setting. These results demonstrate that GeoGebra's efficacy is influenced by student readiness, context, and learning design.

The Effect of Interactive Media Based on DGS and RME on Critical Thinking

The Kolmogorov-Smirnov and Shapiro-Wilk tests gave these results, demonstrating that experimental class data (using DGS interactive media with Geogebra) fails to show normal distribution since all significance values (Sig.) are higher than 0.05. The data from the pretest for the control class followed a normal distribution, whereas the data from the posttest did not. This pattern of distribution has a significant adverse effect on the things that the experimental class learned. The evidence regarding critical thinking skills shows uneven distribution. The subsequent statistical analysis will employ the Wilcoxon test for analysis. The non-normality of this distribution also reflects the variation in student responses to the use of GeoGebra media. This surprising discovery implies that although the media is useful and interactive, not all students may benefit equally from it because of variations in learning styles, digital literacy, or past technological experience. To get better learning outcomes, instructional strategies that use such media should be more precisely adapted to the unique qualities of each learner.

Since the data is not normally distributed, the Wilcoxon test was used as a substitute for the paired sample t-test. The Wilcoxon test results showed that the majority of students in the experimental class experienced an increase in learning outcomes after the intervention, according to the findings of the Wilcoxon Signed-Rank Test analysis displayed above. This is shown by 13 students (out of a total of 19) who had higher posttest scores than the pretest, while only three students experienced a decrease, and three other students experienced no change. Meanwhile, in the control class that used conventional learning, 12 students showed a decline in posttest scores compared to the pretest, and only four students experienced an increase in scores. This indicates that using DGS interactive media (GeoGebra) is superior to traditional approaches in enhancing pupils' critical thinking abilities in rotation content. Based on this finding, the importance of utilizing technology in the learning process of mathematics is highlighted. After conducting the Wilcoxon Test, the research data were analyzed using the homogeneity test.

The Homogeneity Test was used to determine whether the variance of the posttest results from the experimental class and the control class is homogeneous (the same) or heterogeneous (not the same). The test shows a significant value of 0.025 for the mean and 0.032 for the trimmed mean, which are both less than 0.05 based on the homogeneity of variance test results in the table. When viewed through the trimmed mean, this shows that the variation in the data groupings is not homogeneous. Outliers may be the cause of the variance's lack of homogeneity based on the mean and trimmed mean. The assumption of homogeneity may be broken by outliers, which can significantly affect the mean and increase variance in one group more than in others. If the distribution is significantly skewed or contains extreme values, this effect may still be present even though it is lessened in trimmed means.

On the other hand, the groups exhibit homogeneous variation, as evidenced by the non-significant values of 0.127 and 0.130 for the central measures of median and median with modified df tests, which are greater than 0.05. When the data distribution is not normal, the median is a more reliable metric because it is less susceptible to outliers. Thus, the following study will compare the two groups using the Mann-Whitney test.

To ascertain if the experimental group and the control group differ significantly, the Mann-Whitney U test is employed. With a significance threshold of Asymp. Sig. (2-tailed) = 0.018, the test yielded a Z value of -2.367 and a Mann-Whitney U value of 100,000. Given that the significance value is less than 0.05, it can be said that the treatment group and the control group differ significantly from one another (in this case, according to the class variable), suggesting that the participants' outcomes may be impacted by the treatment they received.

To guarantee the validity and consistency of the critical thinking assessment instrument used in this study, the Cronbach's Alpha technique was used to examine the reliability of the pretest and posttest items. According to the findings of the reliability test, the pretest and posttest questions have Cronbach's Alpha values of 0.924 and 0.961, respectively. There were eighteen items in each section of the test. These numbers demonstrate the measurement tool's high degree of reliability and suitability for this investigation.

Descriptive Analysis of Critical Thinking Indicators

To ascertain the precise level of growth of students' critical thinking abilities, a descriptive study of the six critical thinking indicators (interpretation, analysis, evaluation, inference, explanation, and self-regulation) was carried out on both the experimental and control classes. The control class's average score on the interpretation indicator was 1.35 on the pretest with a standard deviation of 1.768, and it decreased to 0.81 on the posttest with a standard deviation of 1.552. On the other hand, the experimental class's posttest score increased from 0.63 with a standard deviation of 1.397 to 1.39 with a standard deviation of 1.830. Pretest scores in the analytical indicator were 1.14 on average with a standard deviation of 1.505, while the posttest scores in the control class were 0.70 with a standard deviation of 1.476. In contrast, the experimental class's average score rose from 0.67 on the pretest with a standard deviation of 1.367 to 1.46 on the posttest with a standard deviation of 1.974.

The control class's assessment indicators decreased from 1.37 with a standard deviation of 2.127 on the pretest to 0.56 with a standard deviation of 1.350 on the posttest. In the experimental class, however, the average score increase from 0.65 with a standard deviation of 1.494 on the pretest to 1.46 with a standard deviation of 1.974 on the posttest. The control class's average score on the pretest for the inference indicator was 1.19 (St = 1.865), but it decreased to 0.56 (standard deviation = 1.402) on the posttest. In the experimental class, the score increased from 0.51 (SD = 1.182) to 1.09 (SD = 1.562). The sixth indicator, explanation, increase in the control class from 0.81 (SD = 1.394) to 0.47 (SD = 1.283).

In the experimental class, the pretest score was 0.40 (SD = 1.015), but there was no posttest data available, or it had not been submitted. The self-regulation indicator indicates a slight rise in the control group, going from 0.81 (standard deviation = 1.552) to 0.32 (standard deviation = 1.038). The experimental class started at 0.25 (standard deviation = 0.830), but we do not have posttest data for this portion yet. There is no post-test data yet because there was not enough time to do the test. Consequently, the majority of pupils failed to finish it. This descriptive research substantiates the conclusion that the utilization of DGS-based interactive media (GeoGebra) in conjunction with the RME strategy is more efficacious in enhancing students' critical thinking abilities overall.

The N-Gain test results for all critical thinking indicators indicate that the average N-Gain in the experimental class is positive. However, in the control class, it is predominantly negative. The experimental class got an average of 2.2679 on the interpretation indicator, whereas the control class got an average of -1.6859. The experimental class got an average of 0.0238 on the analysis indicator, whereas the control class got -0.0146. The evaluation indicator likewise indicated comparable findings, with the experimental class getting 0.0200 and the control class getting -0.0271. The N-gain for the experimental class was 0.0171, whereas the N-gain for the control class plummeted to -0.0233. The explanation indicator showed an average N-gain of 0.0137 for the experimental class and a decline to -0.0110 for the control class. The last indicator, self-regulation, had an average of 0.0113 for the experimental group and a drop to -0.0179 for the control group. Also, the control class's minimum values were usually lower, and the negative skewness values showed that the scores were skewed to the left (meaning they went down). On the other hand, the experimental class had a more even distribution and higher marks. This indicates that the utilization of GeoGebra in the experimental class more successfully fosters the enhancement of students' critical thinking skills in comparison to the control class.

Subsequently, a paired t-test was employed to assess the significance of the changes between the pretest and posttest scores for each critical thinking indicator. The t-test for the control class demonstrated a notable decrease in several indicators: interpretation (p-value = 0.025), evaluation (p-value = 0.006), and inference (p-value = 0.006), despite a substantial effect size on the evaluation indicator (Cohen's d = 2.13). This shows that traditional schooling does not do as good a job of keeping students' critical thinking abilities sharp.

Conversely, the experimental class's scores were better than in almost all indicators, particularly analysis (p-value = 0.005 and Cohen's d = 2.04), inference (p-value = 0.018 and Cohen's d = 1.79), and explanation (p-value = 0.033 and Cohen's d = 1.57). The significant improvement in nearly all indicators in the experimental class indicates that Geogebra-based learning is more effective in enhancing students' critical thinking skills.

■ CONCLUSION

The results of the data and discussion of the study indicate that the use of dynamic geometry software with a realistic mathematical education (RME) approach can help students develop critical thinking skills while learning. This new teaching style with GeoGebra makes students interested by placing concepts in context and using images to help them understand. The GeoGebra program from dynamic geometry software demonstrates that the use of technology in the classroom can help children develop higher-order thinking skills better than traditional techniques, even though both use a realistic mathematical education (RME) approach. The research results also show that the answers of students in the experimental class varied greatly from one another. This highlights how challenging the learning process can be. On the other hand, the control class experienced a significant decline in student participation, underscoring the importance of the teaching method chosen.

These results show us a new way of thinking about how difficult it is to improve mathematical critical thinking skills when using only a realistic mathematics education (RME) approach in contextual learning. However, the introduction discusses the knowledge gap regarding how to use digital technology in real-world learning situations to help students think critically. However, this research can help fill that gap. Combining the realistic mathematics education (RME) approach and GeoGebra in learning or the curriculum has a significant impact on education, especially in mathematics. However, there are some issues with this study, for example, it only focused on one mathematics topic, and the short implementation time. Longitudinal studies with more participants need to be conducted in the future to understand the long-term effects of technology-supported RME. Assessment of teacher readiness to help students in learning needs to be further evaluated.

REFERENCES

Ahmad, N. I. N., & Junaini, S. N. (2020). Augmented reality for learning mathematics: a systematic literature review. *International Journal of Emerging Technologies in Learning*, *15*(16), 106–122. https://doi.org/10.3991/ijet.v15i16.14961

Álvarez-Huerta, P., Muela, A., & Larrea, I. (2022). Disposition toward critical thinking and creative confidence beliefs in higher education students: The mediating role of openness to diversity and challenge. *Thinking Skills and Creativity*, *43,* 101003. https://doi.org/10.1016/j.tsc.2022.101003

Benning, I., Linsell, C., & Ingram, N. (2023). Examining the changes in mathematics teachers' technology dispositions through GeoGebra-mediated professional development. *Asian Journal for Mathematics Education*, *2*(1), 42–63. https://doi.org/10.1177/27527263231163276

Benyamin, B., Qohar, A., & Sulandra, I. M. (2021). *Analisis kemampuan berpikir kritis siswa sma kelas x dalam memecahkan masalah SPLTV* [analysis of critical thinking skills of grade x high school students in solving SPLTV problems]. *Jurnal Cendekia/ : Jurnal Pendidikan Matematika*, *5*(2), 909–922. https://doi.org/10.31004/cendekia.v5i2.574

Dolapcioglu, S., & Doðanay, A. (2022). Development of critical thinking in mathematics classes via authentic learning: an action research. *International Journal of Mathematical Education in Science and Technology*, *53*(6), 1363–1386. https://doi.org/10.1080/0020739X.2020.1819573

Fauzan, A., Harisman, Y., Yerizon, Suherman, Tasman, F., Nisa, S., Sumarwati, Hafizatunnisa, & Syaputra, H. (2024). Realistic Mathematics Education (RME) to improve literacy and numeracy skills of elementary school students based on teachers' experience. *Infinity Journal*, *13*(2), 301–316. https://doi.org/10.22460/

infinity.v13i2.p301-316

Fauzana, R., Dahlan, J. A., & Jupri, A. (2020). The influence of realistic mathematics education (RME) approach in enhancing students' mathematical literacy skills. *Journal of Physics: Conference Series*, *1521*(3). https://doi.org/10.1088/1742-6596/1521/3/032052

Hadi, S., Andriani, P., & Mahfudy, S. (2025). The effect of the implementation of realistic mathematics education assisted by geogebra on students' creative thinking skills at tarbiyatusshibyan islamic junior high school. *Journal of Math Tadris*, *5*(1), 55-67. https://doi.org/10.55099/jurmat.v5i1.189

Hardiyanto, D., Asokawati, I., Majid, P. M., Maesaroh, A. T., & Nursyahidah, F. (2024). Learning reflection using realistic mathematics education assisted by geogebra software. *Mathematics Education Journal*, *18*(1), 15–26. https://doi.org/10.22342/jpm.v18i1.pp15-26

Hidayat, N., & Suryadi, S. (2023). Improving student learning outcomes through the use of digital learning media. *Jurnal Visi Ilmu Pendidikan*, *15*(1), 29-36. https://doi.org/10.26418/jvip.v15i1.54889

Iparraguirre-Villanueva, O., Paulino-Moreno, C., Chero-Valdivieso, H., Espinola-Linares, K., & Cabanillas-Carbonell, M. (2024). Integration of geogebra calculator 3d with augmented reality in mathematics education for an immersive learning experience. *International Journal of Engineering Pedagogy*, *14*(3), 92–107. https://doi.org/10.3991/ijep.v14i3.47323

Ishartono, N., Nurcahyo, A., Waluyo, M., Prayitno, H. J., & Hanifah, M. (2022). Integrating GeoGebra into the flipped learning approach to improve students' self-regulated learning during the COVID-19 pandemic. *Journal on Mathematics Education*, *13*(1), 69–86. https://doi.org/10.22342/jme.v13i1.pp69-86

Kusumah, Y. S., Kustiawati, D., & Herman, T. (2020). The effect of GeoGebra in three-dimensional geometry learning on students' mathematical communication ability. *International Journal of Instruction*, *13*(2), 895–908. https://doi.org/10.29333/iji.2020.13260a

Laurens, T., Batlolona, F. A., Batlolona, J. R., & Leasa, M. (2018). How does realistic mathematics education (RME) improve students' mathematics cognitive achievement? *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 569–578. https://doi.org/10.12973/ejmste/76959

Listiawati, N., Sabon, S. S., Siswantari, Subijanto, Wibowo, S., Zulkardi, & Riyanto, B. (2023). Analysis of implementing Realistic Mathematics Education principles to enhance the mathematics competence of slow learner students. *Journal on Mathematics Education*, *14*(4), 683–700. https://doi.org/10.22342/jme.v14i4.pp683-700

Listyaningrum, P., Retnawati, H., Harun, & Ibda, H. (2025). Realistic mathematics education in digital era elementary schools: a systematic literature review. *International Journal on Advanced Science, Engineering and Information Technology*, *15*(1), 67–74. https://doi.org/10.18517/ijaseit.15.1.20123

Lubis, S. Z., Mahdalena, M., & Zulmaulida, R. (2023). Design of mathematics learning framework based on the perspective of the Qur'an. *Al-Khwarizmi/ : Jurnal Pendidikan Matematika Dan Ilmu Pengetahuan Alam*, *11*(2), 139–150. https://doi.org/10.24256/jpmipa.v11i2.2976

Matsha, V. (2025). Students' intention to adopt a mother-tongue version of the dynamic mathematics software geogebra in their classrooms. *Computers in the Schools*, 1-17 https://doi.org/10.1080/07380569.2025.2459415

Murdiyanto, T., Wijayanti, D. A., & Sovia, A. (2023). Identify slow learners in math: case study in rural schools. *International Journal of Interactive Mobile Technologies*, *17*(6), 45–61. https://doi.org/10.3991/ijim.v17i06.36903

Murni, A., Marsitin, R., & Fayeldi, T. (2022). *Pengembangan LKPD berbasis discovery learning untuk meningkatkan kemampuan berpikir kritis matematis* [development of discovery learning-based student worksheets to improve mathematical critical thinking skills]. *Mathline/ : Jurnal Matematika Dan Pendidikan Matematika*, *7*(1), 1–18. https://doi.org/10.31943/mathline.v7i1.240

Nasrullah, A., Aminah, M., Umalihayati, Rahmadani, K., Widodo, S. A., & Husni, M. (2025). Blended learning in mathematic: the fusion of GeoGebra and Edmodo for enhanced problem-solving abilities. *International Journal of Evaluation and Research in Education*, *14*(1), 423–432. https://doi.org/10.11591/ijere.v14i1.27713

Ndagijimana, J. B., Mukama, E., Lakin, L., Khan, S., Munyaruhengeri, J. P. A., Dushimimana, J. C., Habimana, O., Manirakiza, P., Musengimana, J., & Mushimiyimana, H. (2024). Contributions of GeoGebra software within the socio-cultural proximity on enhancing students' conceptual understanding of mathematics. *Cogent Education*, *11*(1), 2436296.. https://doi.org/10.1080/2331186X.2024.2436296

Palinussa, A. L., Molle, J. S., & Gaspersz, M. (2021). Realistic mathematics education: Mathematical reasoning and communication skills in rural contexts. *International Journal of Evaluation and Research in Education*, *10*(2), 522–534. https://doi.org/10.11591/ijere.v10i2.20640

Putri, A. D., Juandi, D., & Turmudi. (2024). Realistic mathematics education and mathematical literacy: a meta-analysis conducted on studies in Indonesia. *Journal of Education and Learning*, *18*(4), 1468–1476. https://doi.org/10.11591/edulearn.v18i4.21650

Putri, A., Nusantara, T., Purwanto, & As'ari, A. R. (2025). The contribution of critical thinking skills in rich mathematical problem completion: Insights from pre-service mathematics teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, *21*(2), em2581. https://doi.org/10.29333/ejmste/15931

Rahayu, E. G., Widodo, S. A., Al Masjid, A., & Jatmiko, J. (2024). Quality of geometry cards based on augmented reality to improve critical thinking skills in elementary students. *Jurnal Math Educator Nusantara: Wahana Publikasi Karya Tulis Ilmiah di Bidang Pendidikan Matematika*, *10*(2), 241-255. https://doi.org/10.29407/jmen.v10i2.23561

Ramaliana, R., Fajriana, F., & Wulandari, W. (2024, January). Development of teaching modules for merdeka curriculum based on the realistic mathematics education (rme) approach integrated with geogebra software at Sman 1 Muara Batu. In *Proceedings of Malikussaleh International Conference On Education, Social Humanities and Innovation (Miceshi)* (Vol. 1, pp. 0067–0067). https://proceedings.unimal.ac.id/miceshi/article/view/561%0Ahttps://proceedings.unimal.ac.id/miceshi/article/download/561/499

Romero Albaladejo, I. M., & García López, M. del M. (2024). Mathematical attitudes transformation when introducing

GeoGebra in the secondary classroom. *Education and Information Technologies*, *29*(8), 10277–10302. https://doi.org/10.1007/s10639-023-12085-w

Sánchez Noroño, I. V., Juan Luis Prieto, G., Araujo, R. E. G., & Díaz-Urdaneta, S. (2020). On the processes of objectification of geometric knowledge. Analysis of an experience of development of simulators with GeoGebra. In *Educacion Matematica* (Vol. 32, Issue 1, pp. 99–131). Mexican Society for Research and Dissemination of Mathematics Education. https://doi.org/10.24844/EM3201.05

Segal, R., Oxman, V., & Stupel, M. (2021). Using dynamic geometry software to enhance specialized content knowledge: pre-service mathematics teachers' perceptions. *International Electronic Journal of Mathematics Education*, *16*(3), em0647. https://doi.org/10.29333/iejme/11065

Setyawan, D., Anas, A., Nasir, M., & Fadly, D. (2024). Enhancing students' mathematical critical thinking skills through a geogebra integrated project-based learning model. *Journal of Ecohumanism*, *3*(8), 8017–8022. https://doi.org/10.62754/joe.v3i8.5419

Sk, S., & Halder, S. (2020). Critical thinking disposition of undergraduate students in relation to emotional intelligence: Gender as a moderator. *Heliyon*, *6*(11), e05477. https://doi.org/10.1016/j.heliyon.2020.e05477

Suparman, Marasabessy, R., & Helsa, Y. (2024). Fostering spatial visualization in GeoGebra-assisted geometry lessons: A systematic review and meta-analysis. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(9), em2509. https://doi.org/10.29333/ejmste/15170

Susandi, A. D., & Widyawati, S. (2022). Implementation of realistic mathematic education (RME) learning model in improving critical thinking skills. *Al-Jabar/ : Jurnal Pendidikan Matematika*, *13*(2), 251–260. https://doi.org/10.24042/ajpm.v13i2.14996

Susanto, N. C. P., Hartati, S. J., & Standsyah, R. E. (2023). Systematic literature review: application of dynamic geometry software to improve mathematical problem-solving skills. *Mathline/ : Jurnal Matematika Dan Pendidikan Matematika*, *8*(3), 857–872. https://doi.org/10.31943/mathline.v8i3.458

Tamam, B., & Dasari, D. (2021). The use of Geogebra software in teaching mathematics. *Journal of Physics: Conference Series*, *1882*(1), 012042. https://doi.org/10.1088/1742-6596/1882/1/012042

Yildiz, E., & Arpaci, I. (2024). Understanding pre-service mathematics teachers' intentions to use GeoGebra: The role of technological pedagogical content knowledge. *Education and Information Technologies*, *29*(14), 18817–18838. https://doi.org/10.1007/s10639-024-12614-1

Yuan, Z., Liu, J., Deng, X., Ding, T., & Wijaya, T. T. (2023). Facilitating conditions as the biggest factor influencing elementary school teachers' usage behavior of dynamic mathematics software in China. *Mathematics*, *11*(6), 1536. https://doi.org/10.3390/math11061536

Zhu, F., & Xu, B. (2023). The role of dynamic geometry software in teacher–student interactions: stories from three chinese mathematics teachers. *Sustainability (Switzerland)*, *15*(9), 7660. https://doi.org/10.3390/su15097660