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Integrating GeoGebra into the Realistic Mathematics Education Approach: Effects on Students' Mathematical Conceptual Understanding and Mathematical Disposition on Circle Geometry

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ABSTRACT

This study aimed to examine the effect of integrating GeoGebra into the Realistic Mathematics Education (RME) approach on students' conceptual understanding and mathematical disposition in learning circle geometry. A quasi-experimental design employing a pretest–posttest non-equivalent control group design was used. The study was conducted at a public junior high school in Yogyakarta, Indonesia, involving two eighth-grade classes: an experimental class (n = 33) that received RME instruction integrated with GeoGebra, and a control class (n = 33) that received RME instruction without GeoGebra. The research instruments consisted of a conceptual understanding test and a mathematical disposition questionnaire, both of which were validated and demonstrated satisfactory reliability. The results revealed that integrating GeoGebra into the RME approach had a significant effect on students' conceptual understanding and mathematical disposition. Furthermore, students in the experimental class outperformed those in the control class in both conceptual understanding and mathematical disposition. These findings indicate that integrating GeoGebra into the RME approach is effective in strengthening students' conceptual understanding and mathematical disposition in learning circle geometry.

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1. INTRODUCTION

Conceptual understanding is one of the primary goals of mathematics education because it reflects students' ability to understand, connect, and apply mathematical ideas meaningfully across various contexts (Hiebert & Carpenter, 1992). This ability serves as the foundation for the development of mathematical reasoning, communication, problem-solving, and other mathematical competencies (Kilpatrick et al., 2001). However, numerous studies have reported that students' conceptual understanding of mathematics remains relatively low. Hayati & Marlina (2021) found that students' conceptual understanding was categorized as low, while Setiawan et al. (2023) reported that students' average conceptual understanding score on solid geometry topics was only 62.65. These findings indicate that improving students' conceptual understanding continues to be a major challenge in mathematics education.

In addition to cognitive aspects, mathematics education also aims to foster students' mathematical disposition, which refers to their tendency to demonstrate confidence, perseverance, curiosity, and positive attitudes toward mathematics (NCTM, 1989) Mathematical disposition plays an essential role in encouraging students to actively engage in learning and persist when encountering mathematical problems. Nevertheless, previous studies have shown that students' mathematical disposition remains less than optimal. Putri et al. (2023) reported that junior high school students' mathematical disposition had not yet reached a high category, while Nurrizbaeni & Zanthy (2019) found that students' mathematical disposition generally remained at a moderate level. These findings suggest that enhancing students' mathematical disposition deserves equal attention alongside improving their cognitive abilities.

These issues become even more significant in learning circle geometry. Circle geometry is one of the fundamental topics in geometry that supports the development of logical reasoning, problem-solving, and critical thinking skills while serving as a prerequisite for more advanced geometry learning (Mosia & Egara, 2025; Ünlü, 2022). At the junior high school level, this topic includes the elements of a circle, the relationship between central and inscribed angles, circumference, area, arc length, and sector area. However, Demir et al. (2022) reported that students still experience difficulties in distinguishing between the concepts of circumference and area, understanding the relationships among the elements of a circle, and selecting appropriate formulas based on the given information. These findings indicate that instruction on circle geometry should provide students with opportunities to construct mathematical concepts meaningfully rather than merely memorizing formulas.

One instructional approach that aligns with these characteristics is Realistic Mathematics Education (RME). This approach views mathematics as a human activity in which mathematical concepts are constructed through contextual problem-solving and the process of guided reinvention (Gravemeijer, 1994). Previous studies have demonstrated that RME effectively improves students' conceptual understanding of mathematics (Hidayat et al., 2020; Prayitno et al., 2024) while also enhancing their mathematical disposition (Haji et al., 2019; Lubis et al., 2024). However, implementing RME in geometry instruction still presents challenges because manually constructing and exploring geometric objects requires considerable instructional time, which may reduce the effectiveness of the learning process.

One instructional tool with the potential to support the implementation of RME is GeoGebra. GeoGebra is a dynamic mathematics software application that enables students to visualize and explore mathematical concepts interactively, thereby facilitating the development of deeper conceptual understanding (Hamzah & Hidayat, 2022; Muslim et al., 2023). Previous studies have shown that GeoGebra significantly improves students' conceptual understanding of mathematics (Rokan et al., 2023; Uyun et al., 2025). Furthermore, regarding mathematical disposition, Rahman et al. (2025) reported that the use of GeoGebra enhances students' motivation, engagement, and self-confidence in mathematics learning.

The integration of GeoGebra into the Realistic Mathematics Education (RME) approach has also begun to receive attention in previous research. Sari (2017) developed GeoGebra-assisted RME instruction to improve senior high school students' conceptual understanding of limits. In the context of circle geometry, Murni & Jehadus (2019) integrated GeoGebra into RME instruction to develop a learning trajectory that supports students' conceptual understanding. Moreover, the integration of RME and GeoGebra has been employed to improve students' problem-solving skills (Megiana-Pertiwi et al., 2018), spatial ability (Meirida et al., 2021), mathematical abstraction ability (Fitriani et al., 2021), learning outcomes (Antasari et al., 2023), and mathematical literacy (Kartini et al., 2025).

Based on the existing literature, both the RME approach and GeoGebra have individually demonstrated positive contributions to mathematics learning. However, empirical evidence regarding the effectiveness of integrating GeoGebra into the RME approach, compared with RME instruction without GeoGebra, in improving students' conceptual understanding and mathematical disposition in learning circle geometry remains limited. Therefore, this study seeks to provide empirical evidence regarding the effects of integrating GeoGebra into the RME approach on students' conceptual understanding and mathematical disposition in learning circle geometry. Specifically, this study aims to examine the effects of integrating GeoGebra into the Realistic Mathematics Education (RME) approach on students' conceptual understanding and mathematical disposition in the topic of circles.

2. METHOD

This study employed a quantitative approach with a quasi-experimental research design, specifically a pretest–posttest non-equivalent control group design. The study was conducted during the second semester of the 2025/2026 academic year at a public junior high school in Yogyakarta, Indonesia. The sample was selected using purposive sampling, resulting in two Grade VIII classes chosen based on specific criteria, including being taught by the same mathematics teacher, not having previously studied the topic of circles, and having similar learning conditions. The experimental class (n = 33) received Realistic Mathematics Education (RME) integrated with GeoGebra, whereas the control class (n = 33) received RME instruction without GeoGebra.

The research instruments consisted of a conceptual understanding test, a mathematical disposition questionnaire, and a lesson implementation observation sheet. The conceptual understanding test comprised five open-ended items developed based on the indicators of mathematical conceptual understanding for the topic of circles. The instrument development process began with the preparation of a test blueprint, followed by the development of the test items, answer keys, and scoring rubric. The aspects of mathematical conceptual understanding measured by the test are presented in table 1.

Table 1. Aspects and Indicators of Mathematical Conceptual Understanding

Aspect of Mathematical Conceptual Understanding	Indicator of Mathematical Conceptual Understanding
Organizing Mathematical Ideas	• Identifying the essential properties of a mathematical concept. • Distinguishing examples from non-examples. • Determining the criteria for classifying an object into a particular mathematical concept.
Explaining Mathematical Concepts	• Explaining a mathematical concept using one's own words. • Explaining the reasoning behind each step of the solution process.

Connecting Mathematical Ideas	• Connecting two or more related mathematical concepts. • Relating contextual information to mathematical ideas.
Using Mathematical Representations	• Transforming information into various mathematical representations. • Interpreting mathematical representations to understand mathematical concepts.
Applying Mathematical Concepts	• Applying mathematical concepts to solve real-world or novel problems. • Developing alternative solution strategies based on previously understood mathematical concepts.

The mathematical disposition questionnaire was used to measure students' mathematical disposition before and after the intervention. The questionnaire consisted of 24 positive and negative statements developed based on the indicators of mathematical disposition. The instrument development process began with the preparation of a questionnaire blueprint, followed by the development of the questionnaire items and the scoring rubric. The questionnaire employed a five-point Likert scale consisting of Always, Often, Sometimes, Rarely, and Never. Positive statements were scored from 5 to 1, whereas negative statements were scored in reverse from 1 to 5, so that higher scores consistently reflected more positive mathematical dispositions. The aspects and indicators of mathematical disposition measured by the questionnaire are presented in table 2.

Table 2. Aspects and Indicators of Mathematical Disposition

Aspect of Mathematical Disposition	Indicator of Mathematical Disposition
Confidence	• Belief in using mathematics to solve problems. • Confidence in one's mathematical abilities.
Perseverance	• Persisting in completing mathematical tasks. • Not giving up easily and continually seeking alternative solution strategies.
Flexibility	• Being open to new approaches or alternative ideas when the initial strategy is unsuccessful. • Adapting one's way of thinking or solution strategy according to the situation.
Interest	• Demonstrating enthusiasm and motivation in learning mathematics. • Actively asking questions or seeking additional information. • Paying full attention and maintaining focus during the learning process.
Appreciation	• Appreciating the application of mathematics in real-life situations and other disciplines. • Appreciating mathematics as a systematic and logical way of thinking.

The lesson implementation observation sheet was used to assess the fidelity of the learning implementation based on the planned instructional stages. The observation sheet was completed by an observer during each lesson and covered both teacher and student activities throughout the learning process, including the introductory activities, the implementation of the Realistic Mathematics Education (RME) approach integrated with GeoGebra, and the closing activities. A dichotomous scoring system was employed, where a score of 1 was assigned if the observed aspect was implemented and a score of 0 was assigned if it was not implemented.

All research instruments underwent content validation through expert judgment by two mathematics education experts from Universitas Negeri Yogyakarta. The experts evaluated the alignment of each instrument item with the intended indicators, the clarity of the language and wording, and the appropriateness of the scoring rubric, while also providing recommendations for improving the instruments. Based on the validation results, the instruments were revised according to the experts' suggestions and were deemed appropriate for use in the study.

The reliability of the instruments was estimated using Cronbach's alpha based on the pilot-test data. The reliability coefficients were 0.812 for the pretest, 0.830 for the posttest, and 0.936 for the mathematical disposition questionnaire, indicating that all instruments demonstrated satisfactory reliability.

The study was conducted over seven sessions, consisting of a pre-test, five instructional sessions on the topic of circles, and a post-test. In the experimental class, instruction was delivered using the Realistic Mathematics Education (RME) approach integrated with GeoGebra, whereas the control class received RME instruction without GeoGebra. Before the treatment, both groups completed the conceptual understanding test and the mathematical disposition questionnaire as the pre-test. After the instructional intervention was completed, both groups were administered the same test and questionnaire as the post-test.

The data were analyzed using R statistical software through both descriptive and inferential statistics. Descriptive statistics were used to summarize students' conceptual understanding scores, mathematical disposition scores, and the implementation of the instructional process. Prior to hypothesis testing, several assumption tests were conducted, including the Henze–Zirkler test for multivariate normality, the Shapiro–Wilk test for univariate normality, Box's M test for the homogeneity of variance–covariance matrices, and Levene's test for the homogeneity of variances. The effect of integrating GeoGebra into the Realistic Mathematics Education (RME) approach on students' conceptual understanding and mathematical disposition was examined using Hotelling's T^2 test because the study involved two dependent variables that were analyzed simultaneously. Furthermore, the superiority of the instructional approach for each dependent variable was analyzed using an independent-samples t-test with a significance level of 0.05.

3. RESULTS AND DISCUSSION

3.1. Results

Before analyzing the effects of the treatment on students' conceptual understanding and mathematical disposition, the implementation of the instructional process was first evaluated to ensure that the learning activities in both groups were conducted in accordance with the planned instructional procedures. The results of the classroom implementation observations for the experimental and control groups are presented in table 3.

Table 3. Learning Implementation Results

Session	Experimental Group (%)	Control Group (%)
Session I	84%	88%
Session II	100%	92%
Session III	92%	84%
Session IV	92%	88%
Session V	88%	92%
Mean	91.2%	88.8%

Based on Table 3, the average level of learning implementation in the experimental class was 91.2%, while that in the control class was 88.8%. The percentage of learning implementation in both classes indicates that all stages of the instructional process were carried out according to the planned learning scenario and were categorized as very good.

After the learning activities had been implemented according to the planned scenario, a descriptive analysis of students' conceptual understanding of mathematics was conducted based on each aspect. The achievement of each indicator in the experimental and control classes is presented in table 4.

Table 4. Achievement of Mathematical Conceptual Understanding Aspects

Aspects of Mathematical Conceptual Understanding	Experimental Class		Control Class	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
Organizing mathematical ideas	40.91%	86.62%	36.87%	84.09%
Explaining mathematical concepts	26.52%	74.24%	20.83%	67.05%
Connecting mathematical ideas	26.89%	83.33%	26.89%	80.30%
Using mathematical representations	35.98%	75%	36.36%	73.48%
Applying mathematical concepts	26.52%	83.71%	21.97%	79.55%
Total	32.98%	83.02%	30.02%	79.35%

Based on Table 4, the achievement of the aspects of mathematical conceptual understanding in both classes improved from the pre-test to the post-test. The mean achievement in the experimental class increased from 32.98% to 83.02%, while that in the control class increased from 30.02% to 79.35%. Overall, the achievement of the aspects of mathematical conceptual understanding was higher in the experimental class than in the control class.

Furthermore, an analysis was conducted to examine the achievement of students' mathematical disposition aspects in the experimental and control classes. The results of the analysis for each aspect of mathematical disposition are presented in table 5.

Table 5. Achievement of Mathematical Disposition Aspects

Aspects of Mathematical Disposition	Experimental Class		Control Class	
	Pre-scale	*Post-scale*	*Pre-scale*	*Post-scale*
Confidence	57.42%	71.97%	61.52%	67.27%
Perseverance	70.67%	80.12%	67.64%	75.52%
Flexibility	63.03%	73.18%	60.15%	70%
Interest	59.57%	71.52%	60.43%	67.45%
Appreciation	71.67%	90.15%	75.30%	87.48%
Total	66.90%	80.11%	67.35%	76.02%

Based on Table 5, the achievement of the mathematical disposition aspects in both classes improved from the pre-scale to the post-scale. The average achievement in the experimental class increased from 66.90% to 80.11%, while that in the control class increased from 67.35% to 76.02%. Overall, the achievement of the mathematical disposition aspects was higher in the experimental class than in the control class.

Before testing the hypotheses, several prerequisite tests were conducted, including the multivariate normality test, univariate normality test, homogeneity test of the variance–covariance matrices, and homogeneity of variance test. The results indicated that the data on mathematical conceptual understanding and mathematical disposition in both classes were normally distributed both multivariately and univariately and had homogeneous variance–covariance matrices and variances. Therefore, all assumptions required for the analysis were satisfied, allowing the hypothesis testing to proceed using parametric statistical analyses.

The initial ability test was conducted to determine whether there were any differences in the initial abilities of the experimental and control classes before the treatment was administered. The results of Hotelling's T^2 test are presented in Table 6.

Table 6. Results of the Mean Difference Test Before Treatment

Data	T^2	*p-value*
Pre-test scores of mathematical conceptual understanding and mathematical disposition	2.7403	0.0723

Based on Table 6, the *p-value* > 0.05, indicating that there was no statistically significant difference in the initial abilities of the experimental and control classes. Therefore, the two classes had equivalent initial abilities before the treatment was administered.

Furthermore, a hypothesis test was conducted to examine the effect of integrating GeoGebra into the Realistic Mathematics Education (RME) approach on students' mathematical conceptual understanding and mathematical disposition simultaneously. The results of the Hotelling's T^2 test are presented in Table 7.

Table 7. Results of Hotelling's T^2 Test for the Effect of the Treatment

Data	T^2	*p-value*
Post-test scores of mathematical conceptual understanding and mathematical disposition	4.1933	0.01951

Based on Table 7, the *p-value* < 0.05, indicating a statistically significant simultaneous difference between the experimental and control classes in terms of mathematical conceptual understanding and mathematical disposition. These findings indicate that integrating GeoGebra into the Realistic Mathematics Education (RME) approach had a significant effect on both variables.

Furthermore, to determine which variable contributed to the difference between the two groups, an independent-samples *t*-test was conducted for each variable separately. The results of the analysis are presented in table 8.

Table 8. Results of the Group Comparison

Data	t	*p-value*
Post-test scores of mathematical conceptual understanding	2.6748	0.0047
Post-scale scores of mathematical disposition	2.5801	0.0061

Based on Table 8, the *p-value* < 0.05, indicating statistically significant differences between the experimental and control classes in both mathematical conceptual understanding and mathematical disposition. These results indicate that students who received GeoGebra-assisted Realistic Mathematics Education (RME) instruction demonstrated better mathematical conceptual understanding and mathematical disposition than those who received the RME approach without GeoGebra.

3.2. Discussion

The findings of this study indicate that integrating GeoGebra into the Realistic Mathematics Education (RME) approach had a significant effect on students' mathematical conceptual understanding. Furthermore, students who received GeoGebra-assisted RME instruction demonstrated better mathematical conceptual understanding than those who received the RME approach without GeoGebra. These findings suggest that the integration of GeoGebra not only supports concept visualization but also strengthens students' knowledge construction throughout the learning process.

The improvement in students' mathematical conceptual understanding can be attributed to the opportunities provided by GeoGebra for students to dynamically explore circle concepts through object manipulation, pattern observation, and the investigation of relationships among mathematical concepts. Rather than merely facilitating calculations, GeoGebra helps students focus on conceptual relationships, such as those among the radius, diameter, central angle, arc length, and sector area. Consequently, students are able to construct mathematical concepts through exploration and discovery rather than through rote memorization of formulas. This finding is consistent with the principle of guided reinvention in RME, which positions students as active participants in constructing mathematical knowledge.

From the perspective of the characteristics of RME, the integration of GeoGebra supports its five key characteristics: the use of meaningful contexts, the use of models, students' contributions, interactivity, and the interconnectedness of mathematical concepts. Dynamic visualizations help students connect contextual problems with mathematical representations, while object manipulation enables them to develop models, test conjectures, and gradually construct mathematical concepts. In addition, the results of students' explorations using GeoGebra serve as the basis for classroom discussions, thereby facilitating both horizontal and vertical mathematization. Therefore, GeoGebra does not replace students' thinking processes but rather facilitates the construction of mathematical concepts, which is the central principle of the RME approach.

The findings of this study are supported by previous research demonstrating that integrating GeoGebra into the Realistic Mathematics Education (RME) approach enhances students' mathematical conceptual understanding. Ramadhan et al. (2025) reported that GeoGebra-assisted RME was effective in improving students' mathematical conceptual understanding. Murni & Jehadus (2019) explained that GeoGebra's dynamic visualizations help students construct geometric concepts more effectively, whereas Akbas & Alan (2022) found that dynamic mathematics software facilitates students' transition from informal understanding to formal mathematical concepts through visual exploration. Furthermore, Seloane et al. (2023) reported that GeoGebra helps students connect multiple mathematical representations, thereby strengthening their conceptual understanding. Consistent with these findings, Turgut, (2022) argued that integrating GeoGebra with the principles of RME enables students to reinvent mathematical concepts through dynamic visual exploration, making the process of conceptual understanding more meaningful. The present study extends previous research by not only confirming the benefits of integrating RME and

GeoGebra for students' mathematical learning but also providing empirical evidence that this integration leads to better mathematical conceptual understanding than the implementation of the RME approach without GeoGebra in learning the topic of circles.

The findings of this study indicate that integrating GeoGebra into the Realistic Mathematics Education (RME) approach had a significant effect on students' mathematical disposition. Furthermore, students who received GeoGebra-assisted RME instruction demonstrated better mathematical disposition than those who received the RME approach without GeoGebra. These findings suggest that the use of GeoGebra not only supports students' cognitive development but also strengthens their positive attitudes toward learning mathematics.

The improvement in students' mathematical disposition can be attributed to the opportunities provided by GeoGebra-assisted RME for students to actively explore mathematical concepts through dynamic and interactive visualizations. Throughout the learning process, students were encouraged to formulate conjectures, test the results of their explorations, engage in discussions, and draw conclusions based on their own findings. These learning activities fostered students' confidence, perseverance, flexibility in selecting problem-solving strategies, interest in learning mathematics, and appreciation of the interconnectedness of mathematical concepts. Consequently, students not only developed a deeper conceptual understanding but also cultivated more positive attitudes toward learning mathematics.

In addition, the use of GeoGebra reduced the burden of repetitive procedural activities, such as manually drawing and measuring geometric objects, allowing students to devote more time to discussion, exploration, and reflection on their findings. As a result, the learning process became more engaging, interactive, and meaningful, thereby encouraging greater student participation during classroom activities. This active engagement is one of the factors contributing to the development of students' mathematical disposition.

The findings of this study are consistent with those of previous research. Rosyid & Umbara (2019) reported that the use of GeoGebra promotes positive attitudes toward mathematics by providing engaging visualizations and more meaningful learning experiences. Similarly, Zetriuslita et al. (2021) explained that GeoGebra's dynamic visualizations encourage students to explore mathematical concepts independently, thereby increasing their confidence in solving mathematical problems. In addition, Priatna et al. (2018) found that GeoGebra enhances students' enthusiasm, optimism, and perseverance by enabling them to explore various problem-solving strategies dynamically. These findings are further supported by Zagoto et al. (2025), who reported that the use of GeoGebra improves students' self-confidence, curiosity, and positive attitudes toward mathematics. Likewise, Rahman et al. (2025) explained that GeoGebra fosters students' perseverance by encouraging them to continuously explore multiple problem-solving strategies and persist when encountering difficulties. Their study also showed that GeoGebra helps students develop cognitive flexibility through the exploration of various solution strategies and enhances their appreciation of mathematics by enabling them to recognize its connections to real-life situations. Furthermore, Jabnabillah & Reza (2022) reported that the use of GeoGebra increases students' interest in learning, making them more enthusiastic and actively engaged throughout the learning process.

The present study extends these previous findings by providing empirical evidence that integrating GeoGebra into the RME approach results in better mathematical disposition than implementing the RME approach without GeoGebra in learning the topic of circles.

The findings of this study suggest that integrating GeoGebra into the Realistic Mathematics Education (RME) approach can serve as an effective instructional strategy for simultaneously enhancing students' conceptual understanding and mathematical disposition.

For mathematics teachers, these findings highlight the importance of utilizing interactive technology to support contextual learning, promote conceptual exploration, and facilitate students' construction of mathematical understanding through dynamic visual representations. For curriculum developers and schools, the results provide empirical evidence supporting the integration of dynamic mathematics software such as GeoGebra into the development of instructional materials and the implementation of technology-enhanced learning within the School Operational Curriculum. Furthermore, these findings may serve as a reference for future studies investigating the effectiveness of integrating GeoGebra into the RME approach across different mathematical topics, educational levels, and mathematical competencies, thereby providing a more comprehensive understanding of its implementation in diverse learning contexts.

This study has several limitations that should be considered when interpreting the findings. First, the study was conducted in only one public junior high school and involved two Grade VIII classes, which may limit the generalizability of the findings. In addition, the intervention focused solely on the topic of circles and was implemented over five instructional meetings. Therefore, the effectiveness of integrating GeoGebra into the RME approach for other mathematical topics or over a longer instructional period requires further investigation. From an implementation perspective, the study was conducted during the month of Ramadan, when instructional time was shorter than under normal conditions, and several school activities affected the planned instructional schedule. Furthermore, students in the experimental class required an initial adaptation period to become familiar with GeoGebra, which limited the optimal implementation of several learning activities during the early stages of the intervention. Therefore, the findings of this study should be interpreted within the context of these limitations.

4. CONCLUSION

This study demonstrates that integrating GeoGebra into the Realistic Mathematics Education (RME) approach has a significant effect on students' mathematical conceptual understanding and mathematical disposition in learning the topic of circles. The integration of GeoGebra supports a more interactive and meaningful learning process, enabling students to develop a deeper conceptual understanding while fostering more positive mathematical dispositions. Furthermore, students who received GeoGebra-assisted RME instruction demonstrated better mathematical conceptual understanding and mathematical disposition than those who received the RME approach without GeoGebra.

REFERENCES

Akbas, E. E., & Alan, K. (2022). Examining 6th Grade Students' Learning of the Subject of Volume with GeoGebra Software Within the Framework of RME Approach. *Open Journal for Educational Research*, *6*(1), 89–104. https://doi.org/10.32591/coas.ojer.0601.07089e

Antasari, M., Hanifah, H., Susanta, A., & Andriani, I. (2023). Penerapan Pendekatan Realistic Mathematics Education Melalui Model Apos Berbantuan Geogebra untuk Meningkatkan Hasil Belajar Matematika. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(2), 2468–2478. https://doi.org/10.24127/ajpm.v12i2.6928

Demir, M., Zengin, Y., Özcan, Ş., Urhan, S., & Aksu, N. (2022). Students' mathematical reasoning on the area of the circle: 5E-based flipped classroom approach. *International*

Journal of Mathematical Education in Science and Technology, *54*(1), 99–123. https://doi.org/10.1080/0020739X.2022.2101955

Fitriani, N., Hidayah, I. S., & Nurfauziah, P. (2021). Live Worksheet Realistic Mathematics Education Berbantuan Geogebra: Meningkatkan Abstraksi Matematis Siswa SMP pada Materi Segiempat. *JNPM (Jurnal Nasional Pendidikan Matematika)*, *5*(1), 37–50. https://doi.org/10.33603/jnpm.v5i1.4526

Gravemeijer, K. (1994). *Developing Realistic Mathematics Education*. CD β Press.

Haji, S., Yumiati, & Zamzaili. (2019). Improving Students' Productive Disposition through Realistic Mathematics Education with Outdoor Approach. *Journal of Research and Advances in Mathematics Education*, *4*(2), 101–111. https://doi.org/10.23917/jramathedu.v4i2.8385

Hamzah, N. A. H., & Hidayat, R. (2022). The Role of Geogebra Software in Mathematics Education: A Systematic Literature Review. *Jurnal Pendidikan Sains Dan Matematik Malaysia*, *12*(1), 24–38. https://doi.org/10.37134/jpsmm.vol12.1.3.2022

Hayati, S. I., & Marlina, R. (2021). Analisis Kemampuan Pemahaman Konsep Matematis Siswa Kelas VII SMP pada Materi Bentuk Aljabar di SMP IT Nurul Huda Batujaya. *Jurnal Pembelajaran Matematika Inovatif*, *4*(4). https://doi.org/10.22460/jpmi.v4i4.827-834

Hidayat, E. I. F., Yandhari, I. A. V., & Alamsyah, T. P. (2020). Efektivitas Pendekatan Realistic Mathematics Education (RME) Untuk Meningkatkan Kemampuan Pemahaman Konsep Matematika Siswa Kelas V. *Jurnal Ilmiah Sekolah Dasar*, *4*(1), 106–113. https://doi.org/10.23887/jisd.v4i1.21103

Hiebert, J., & Carpenter, T. P. (1992). Learning and teaching with understanding. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 65–97). Macmillan Publishing.

Jabnabillah, F., & Reza, W. (2022). Pengaruh Penggunaan Aplikasi GeoGebra Terhadap Minat Belajar Siswa Pada Pembelajaran Matematika. *Pi: Mathematics Education Journal*, *5*(2), 94–100. https://doi.org/10.21067/pmej.v5i2.7468

Kartini, N., Retnawati, H., & Arliani, E. (2025). The Effectiveness Of Realistic Mathematics Education (RME) Assisted By GeoGebra On Students' Mathematical Literacy. *International Journal of Multicultural and Multireligious Understanding*, *12*(9), 39–50. https://doi.org/10.18415/ijmmu.v12i9.6998

Kilpatrick, Jeremy., Swafford, Jane., & Findell, B. (Eds.). (2001). *Adding it up : helping children learn mathematics*. National Academy Press.

Lubis, E. R., Fauzi, KMS. M. A., & Mulyono, M. (2024). Development of A Learning Model Based on RME for Improving Mathematical Literacy Skills and Students' Mathematical Disposition. *Jurnal Paedagogy*, *11*(3), 612. https://doi.org/10.33394/jp.v11i3.11544

Megiana-Pertiwi, C., Fitriani, T., & Afrilianto, M. (2018). Relasi antara Kemampuan Pemecahan Masalah Matematik dan Keaktifan Belajar Matematik Siswa SMP yang Menggunakan Pendekatan Realistic Mathematic Education Berbantuan GeoGebra. *JPMI - Jurnal Pembelajaran Matematika Inovatif*, *1*(4), 513–524. https://doi.org/10.22460/jpmi.v1i4.p513-524

Meirida, U., Johar, R., & Ahmad, A. (2021). Pengembangan lintasan belajar limas untuk mengembangkan kemampuan spasial siswa melalui pendidikan matematika realistik berbantuan GeoGebra. *PYTHAGORAS Jurnal Pendidikan Matematika*, *16*(1), 1–18. https://doi.org/10.21831/pg.v16i1.36157

Mosia, M., & Egara, F. O. (2025). Enhancing achievement and retention in circle geometry through digital storytelling for senior secondary learners. *Education and Information Technologies*, *30*(17), 25081–25111. https://doi.org/10.1007/s10639-025-13702-6

Murni, V., & Jehadus, E. (2019). Learning Circle through Geogebra Media Oriented to Understanding Concepts. *International Journal of Innovative Science and Research Technology*, *4*(5), 391–394. https://www.ijisrt.com/learning-circle-through-geogebra-media-oriented-to-understanding-concepts

Muslim, N. E. I., Zakaria, M. I., & Yin Fang, C. (2023). A Systematic Review of GeoGebra in Mathematics Education. *International Journal of Academic Research in Progressive Education and Development*, *12*(3). https://doi.org/10.6007/ijarped/v12-i3/19133

NCTM. (1989). *Curriculum and evaluation standards for school mathematics*. NCTM. http://www.archive.org/details/curriculumevaluaOOnati

Nurrizbaeni, N., & Zanthy, L. S. (2019). Analisis Kemampuan Komunikasi Matematik dan Disposisi Matematik Siswa Mts Nurul Hatta Kelas VII pada Materi Himpunan. *Journal On Education*, *01*, 29–36. https://doi.org/10.31004/joe.v1i3.112

Prayitno, S. H., Gunawan, W., Fiantika, F. R., Hartono, & Holisin, I. (2024). Realistic Mathematics Education (RME) Learning Model Improves Conceptual and Procedural Understanding of Junior High School Students. *JPI (Jurnal Pendidikan Indonesia)*, *13*(2), 317–325. https://doi.org/10.23887/jpiundiksha.v13i2.75228

Priatna, N., Martadiputra, B. A. P., & Wibisono, Y. (2018). Developing geogebra-assisted reciprocal teaching strategy to improve junior high school students' abstraction ability, lateral thinking and mathematical persistence. *Journal of Physics: Conference Series*, *1013*(1). https://doi.org/10.1088/1742-6596/1013/1/012142

Putri, A. G. E., Priyadi, R., & Khoirunnisa, K. (2023). Perbedaan disposisi matematika siswa yang mengikuti kursus dan tidak mengikuti kursus: mana yang lebih baik? *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *6*(4), 1505–1512. https://doi.org/10.22460/jpmi.v6i4.17301

Rahman, M., Hamid, A., & Asmaun, A. (2025). Enhancing Students' Strategic Competence with GeoGebra and Productive Disposition: Elevating Mathematics Learning in the Digital Age. *International Journal of Education in Mathematics, Science and Technology*, *13*(4), 930–946. https://doi.org/10.46328/ijemst.4923

Ramadhan, F., Mahmudi, A., & Nabilla, H. A. (2025). Effectiveness of GeoGebra-Assisted Realistic Mathematics Education in Enhancing Students' Conceptual Understanding. *Edumatica: Jurnal Pendidikan Matematika*, *15*(3), 402–416. https://doi.org/10.22437/edumatica.vl5i3.45514

Rokan, N., Elmania, P., Sihombing, F. G., Hasibuan, A. M., & Rizqi, N. R. (2023). Development of Problem-Based Learning-Based Mathematics with the Assistance of GeoGebra Applications to Improve Students' Mathematical Concepts Understanding Ability. *Jurnal Eduscience (JES)*, *10*(2), 451–467. https://doi.org/10.36987/jes.v10i2.4584

Rosyid, A., & Umbara, U. (2019). Analysis of students' attitudes towards implementation of geogebra-assisted missouri mathematics project. *Journal of Physics: Conference Series*, *1265*(1). https://doi.org/10.1088/1742-6596/1265/1/012009

Sari, P. (2017). GeoGebra as a Means for Understanding Limit Concepts. *Southeast Asian Mathematics Education Journal*, *7*(2), 71–80. https://doi.org/10.46517/seamej.v7i2.55

Seloane, P. M., Ramaila, S., & Ndlovu, M. (2023). Developing undergraduate engineering mathematics students' conceptual and procedural knowledge of complex numbers using GeoGebra. *Pythagoras - Journal of the Association for Mathematics Education of South Africa*, *44*(1), 1–14. https://doi.org/10.4102/pythagoras.v44i1.763

Setiawan, S., Julrissani, J., & Savira, L. (2023). Analisis Kemampuan Pemahaman Konsep Matematis Siswa pada Materi Bangun Ruang Sisi Datar. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(1), 80–91. https://doi.org/10.24127/ajpm.v12i1.5106

Turgut, M. (2022). Reinventing Geometric Linear Transformations in a Dynamic Geometry Environment: Multimodal Analysis of Student Reasoning. *International Journal of Science and Mathematics Education*, *20*(6), 1203–1223. https://doi.org/10.1007/s10763-021-10185-y

Ünlü, M. (2022). Investigation of preservice mathematics teachers' concept definitions of circle, circular region, and sphere. *International Journal of Mathematical Education in Science and Technology*, *53*(7), 1787–1814. https://doi.org/10.1080/0020739X.2020.1847334

Uyun, F. I., Buchori, A., & Endahwuri, D. (2025). Effectiveness of GeoGebra-Based Interactive Multimedia to Improve Mathematical Concept Understanding Ability. *Kontinu: Jurnal Penelitian Didaktik Matematika*, *9*(1), 23–28. https://doi.org/10.30659/kontinu.9.1.23-38

Zagoto, M. M., Musdi, E., Arnawa, I. M., Fauzan, A., Bentri, A., & Dakhi, O. (2025). Effectiveness of Geogebra-Based Learning on Students' Cognitive and Affective Participation in Mathematics. *Salud, Ciencia y Tecnologia*, *5*(2001), 1–12. https://doi.org/10.56294/saludcyt20252001

Zetriuslita, Nofriyandi, & Istikomah, E. (2021). The Increasing Self-Efficacy and Self-Regulated through Geogebra Based Teaching reviewed from Initial Mathematical Ability (IMA) Level. *International Journal of Instruction*, *14*(1), 587–598. https://doi.org/10.29333/iji.2021.14135a