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Comparison of Student's Mathematical Problem-Solving Ability between Realistic Mathematics Education Assisted by GeoSpace and Direct Instruction

Febi Ayumni[1*], Himmatul Ulya[2], Sumaji[3]

[1,2,3]Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Muria Kudus

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ABSTRACT

This study compares students' mathematical problem-solving skills between those taught using the GeoSpace-assisted Realistic Mathematics Education (RME) model and those taught through direct instruction. A quantitative approach with a quasi-experimental nonequivalent control group design was employed. The participants were two eighth-grade classes at a junior high school, with one class assigned as the experimental group and the other as the control group. Mathematical problem-solving skills were measured using an essay test based on NCTM indicators: understanding problems, planning strategies, implementing solutions, and reviewing results. The instrument demonstrated adequate validity and reliability. The experimental group received instruction using the RME model supported by the GeoSpace application, while the control group received direct instruction without digital media. Data analysis using an independent samples t-test showed that the experimental group achieved significantly higher posttest scores than the control group ($p < 0.05$), with a moderate effect size. In addition, learning gains in the experimental group were higher than those in the control group. These findings indicate that the GeoSpace-assisted RME model is more effective in improving students' mathematical problem-solving skills than direct instruction. The use of realistic contexts and interactive visual representations supports students' conceptual understanding. However, as the study involved only two classes, further research with a broader sample is recommended to strengthen the generalizability of the results.

Corresponding Author:

Febi Ayumni
Department of Mathematics Education,
Faculty of Teacher Training and Education,
Universitas Muria Kudus
North Ring Road, Kayuapu Kulon, Gondangmanis, Bae District, Kudus Regency, Central Java 59327, Indonesia
Email: 202135008@std.umk.ac.id

Introduction

Education is seen as a process that is consciously designed to build a learning environment that supports the spiritual, intellectual, and social development of students. Educational activities take place throughout human life and are not limited to formal institutions. Law of the Republic of Indonesia Number 20 of 2003 concerning the National Education System emphasizes that the purpose of education is to form individuals who are faithful, pious, independent, and responsible. This view is in line with the thinking of Ki Hajar Dewantara who emphasized that education is an effort to guide the natural potential of children so that they grow into individuals with strong character and can play the role of members of a civilized society (Pristiwanti et al., 2022).

Mathematics is a fundamental discipline that plays a significant role in the advancement of science, technology, and daily activities. Mathematics learning not only functions as a medium for presenting information through models, graphs, or tables, but also as a means of developing logical, orderly, and systematic thinking skills. Thus, the mathematics learning process should not be limited to counting skills alone but needs to be directed to cultivate students' reasoning skills and skills in solving various mathematical problems. Therefore, the right learning strategies or methods are needed to help overcome and reduce various difficulties experienced by students in mathematics subjects. One of the approaches that can be used is the application of learning methods that are able to provide a memorable learning experience for students during the process (Hayati & Jannah, 2024; Lucianinisita & Rahaju, 2020; Indah Suciati, 2021).

Problem-solving skills are included in the category of higher *order thinking skills* that students need to deal with various problems in the context of mathematics. This ability involves a series of steps that include the process of understanding the problem, designing a solution strategy, implementing the plan that has been prepared, and re-evaluating the results obtained. Students are required to process information rationally and apply it systematically according to the context of the problem at hand. According to the National Council of Teachers of Mathematics, mathematical problem-solving skills can be seen through five indicators, namely identifying the main information in the problem, building an appropriate mathematical model, determining effective solution strategies, interpreting results based on the context of the problem, and applying mathematical concepts precisely in other similar situations (Anis Sulistifa et al., 2025; Rismawati et al., 2022; Faraditha et al., 2025; Mauleto, 2024).

The problem-solving steps offered by Polya, namely understanding the problem, developing a solution plan, implementing the chosen strategy, and reassessing the results, are in accordance with the horizontal and vertical mathematicization process that is the core of the *Realistic Mathematics Education* (RME) approach. Through these stages, students are directed to relate real situations into mathematical forms (horizontal mathematicalization) and generalize concepts towards formal knowledge (vertical mathematicalization). Therefore, the application of mathematics learning based on RME is believed to be able to strengthen students' problem-solving skills through more meaningful thinking activities related to real situations (Saedi et al., 2011; Purwati, 2020).

However, the results of international assessments show that the mathematical problem-solving skills of Indonesian students are still relatively low. The results *of the Programme for International Student Assessment (PISA)* in 2022 noted that the mathematics score of Indonesian students was at 366, a decrease of 13 points compared to 2018. This condition is in line with the findings of initial observations at SMP Negeri 1 Jekulo Kudus in 2024. Of the 30 students who took the diagnostic test of problem-solving skills, an average score of 16.33 was obtained which was in the category of "newly developed." The information was obtained

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through a description test compiled based on NCTM indicators and assessed using rubrics that had been validated by two mathematics education experts. These findings suggest that students' mathematical problem-solving skills still need improvement through the application of more contextual and meaningful learning approaches (OECD, 2019).

The RME approach combined with the use of concrete media has been widely studied, including the use of counting glass media in learning number counting operations. The findings of the study show that the application of RME with the support of concrete media is able to increase students' mathematical problem-solving ability effectively. However, the research still focuses on the use of real media that is limited to manipulative activities in the classroom and has not touched the realm of interactive digital media.(Utami et al., 2025)

Along with the development of information and communication technology, opportunities for the application of the RME approach through interactive digital media are increasingly open. One of the relevant innovations is the use of the GeoSpace application, which is an Android-based learning media that supports mathematics learning through three-dimensional interactive visualization (*3D visualization*). This application contains learning video features, quizzes, practice questions, motivational videos, and visualizations of 3D objects that can be played and enlarged. In this study, GeoSpace is not only used as a visualization tool, but also as a medium of horizontal mathematicalization, which allows students to express real models into formal geometric shapes and understand the dynamic interconnectedness between spatial elements. Through this dynamic geometric environment, abstract concepts such as flat-sided space can be understood more concretely and contextually (Lestari et al., 2025).

The results of the study Melati et al. (2024) show that the use of interactive visualization-based media such as *GeoSpace* can increase student engagement while strengthening the vertical mathematical process in RME-approached learning. The findings are consistent with Lestari et al. (2025), also revealing that the use of RME combined with digital technology can significantly improve conceptual understanding and mathematical problem-solving skills. Therefore, RME's integration with *GeoSpace* has great potential to help students master geometry concepts through more active, contextual, and meaningful learning experiences (Asmaarobiyah et al., 2025).

Theoretically, this study involves two independent variables and one bound variable. The first free variable is the *Realistic Mathematics Education (RME)* learning model combined with *GeoSpace*, while the second free variable is the direct instruction model. The bound variable in this study is the mathematical problem-solving ability of students. The two learning approaches were analyzed to see their effectiveness in improving problem-solving skills in flat side room building materials. The RME approach is in line with the principles of the Independent Curriculum which emphasizes experiential learning and problem-solving that departs from the real context, through differentiation of learning processes and outcomes. The novelty in this study lies in the combination of the RME model with *the GeoSpace application* as an interactive visualization-based learning media implemented within the framework of the Independent Curriculum. In addition, this study also presents a direct comparison with conventional learning to assess the extent to which the improvement of mathematical problem-solving skills of junior high school students can be achieved.

Method

Types of Research

This research is categorized as quantitative research with a *quasi-experimental research* design. The selection of this design was based on the purpose of the research, which was to test the effectiveness of the *application of the Realistic Mathematics Education (RME)* model combined with *the GeoSpace* application on students' mathematical problem-solving skills.

In this study, the researcher did not apply a full randomization process in determining the group, but used classes that had been formed as experimental groups and control groups. This approach provides an opportunity for researchers to compare changes in student learning outcomes that take part in RME learning assisted by *the GeoSpace* application with the learning outcomes of students who receive conventional direct learning.

This study applied a *pretest–posttest nonequivalent control group* design, where both groups were first given *a pretest* to identify initial ability. After that, each group received learning treatment according to the model that had been set, and the research process ended with the provision of *a posttest* as an instrument to measure learning outcomes.

Table 1. Research Design Design

Groups	*Pretest* (O_1)	Treatment	*Postest* (O_2)
Experimental Classes	O_1	GeoSpace-assisted RME (X)	O_2
Control Class	O_1	Live learning	O_2

With:
O_1 = *pre-test score*
O_2 = final test score *(post-test)*
X = treatment with GeoSpace-assisted RME models

Population and Sample

The population in this study includes all grade VIII students at one of the State Junior High Schools in Kudus Regency in the 2024/2025 school year. Sample selection was carried out through *purposive cluster sampling technique* by considering the uniformity of academic characteristics between classes. From this process, two classes were designated as research samples, namely class VIII C (32 students) as the experimental group and class VIII D (32 students) as the control group, so that the total sample consisted of 64 students. Both classes are guided by the same teacher to minimize the influence of teacher *variables*. Materials, time allocation, and learning objectives are made uniform through the Learning Implementation Plan (RPP), with differences lying in the learning model used. The intervention was carried out for six meetings on the topic of Building a Flat Side Space.In the experimental group, students participated in RME-based learning that utilized GeoSpace applications for concept exploration and 3D visualization, while the control group received direct (conventional) learning.

Instruments

The research instrument used was in the form of a description test designed to measure students' mathematical problem-solving ability. The preparation of this instrument refers to problem-solving indicators according to Polya and NCTM, which include the ability to understand problems, formulate solution strategies, implement planned strategies, and review and evaluate the results of solutions. This approach is used so that the instrument can comprehensively describe the student's thinking process and in accordance with the characteristics of the mathematical problem-solving task (Fitrianty et al., 2022). The test consists of 16 questions developed based on these indicators and validated by five experts using *the Aiken's V method*. The validation results showed a coefficient value between 0.79–0.96, so that all items met the content validity criteria. After the trial, 8 valid questions were obtained and 4 of the best questions were selected for research. Each question is designed to measure all four indicators with an analytical score of 0–4 per indicator, so the maximum total score is 16.

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The internal reliability coefficient (Cronbach's α) was 0.87, and the *inter-rater reliability* was 0.74, indicating high consistency between raters.

Table 2. Mathematical Malala Solving Ability Test Instrument

No.	Indicator NCTM	Sample Question Items (Essay)	Polya's Problem Solving Stage
1	Understanding the problem	A block-shaped box measures 25 cm long, 15 cm wide, and 10 cm high. The box will be wrapped in wrapping paper. Write down the information you know and what is asked!	Understand the problem
2	Planning the solution	Based on the problem in number 1, write down the steps or strategies that you will use to determine the surface area of the block. Explain the chosen formula!	Devise a plan
3	Carrying out the plan	Calculate the surface area of the block in question number 1 according to the strategy you have written!	Carry out the plan
4	Looking Back	A cube has a rib length of 14 cm. Once you've got the surface area, explain if your answer is correct and state why!	Look back

Data Collection

Research data was obtained in the even semester of the 2024/2025 academic year through three series of activities, namely the provision of pretests, the implementation of learning treatments, and the provision of posttests. The pretest is given to identify the student's initial ability in mathematical problem solving before receiving the learning treatment. The learning treatment was carried out for six meetings. In the experimental class, learning uses the Realistic Mathematics Education (RME) model with the help of the GeoSpace application, while the control class follows learning with a direct instruction model. The learning process in the experimental class includes the context exploration stage through the introduction of real situations related to the construction of flat-sided spaces, followed by horizontal mathematics using GeoSpace as an interactive digital media that facilitates visualization as well as the conversion of real situations into formal representations of three-dimensional geometry, and ends with the reflection and generalization stage through discussion and conclusion of concepts. After all learning interventions are completed, a posttest is given to assess the improvement of students' mathematical problem-solving abilities. In addition to tests, observation of student activities and documentation of the learning process are also used as supporting data (Nuralan, 2022).

Data Analysis

Initial data analysis and final data analysis are the two analysis techniques used in this study. The *pretest value* of mathematical problem-solving ability in both the experimental group and the control group was analyzed through the initial data analysis stage. Before treatment is administered, this analysis aims to assess whether there is a significant difference and check the average equivalence between the two groups. This stage is carried out through statistical analysis which includes a normality test, a variance homogeneity test, and an average similarity test. The test results showed that Ramadhani et al. (2022) *the pretest data* from the two groups were not normally distributed, the variance was homogeneous, and there was a significant difference in mean size.

After each group received a different treatment, a final data analysis was carried out. This analysis aimed to assess changes in mathematical problem-solving skills after the intervention, as well as compare the effectiveness of the learning models used in the two groups. While the experimental group used the RME approach with the help of the GeoSpace application, the control group used conventional learning. After treatment, a *posttest* was performed on both groups to assess the impact of the treatment on their mathematical problem-solving abilities. At this stage, statistical analysis includes normality tests, homogeneity tests, and hypothesis testing to assess the extent to which the treatment given shows its effectiveness.

Microsoft Excel and SPSS software were used to analyze the difference in average mathematical problem-solving ability between the experimental group and the control group. The Normalized Gain (N-Gain) value calculated from *the pretest* and *posttest* scores of each group is used as the basis for assessing the effectiveness of the treatment. Through these calculations, the level of improvement in ability obtained through the application of GeoSpace application-assisted RME learning in the experimental group was compared with the increase produced by conventional learning in the control group. It is then interpreted according to calcification in Lestari & Yudhanegara (2015).

Table 3. Normalized Gain Interpretation

N-Gain *Value*	**Criteria**
N-Gain ≥ 0.70	Height
0.30 ≤ *N-Gain* < 0.70	Medium
N-Gain < 0.30	Low

Research Findings

The purpose of this study is to obtain preliminary data and final data to assess whether the application of the *GeoSpace-assisted Realistic Mathematics Education* (RME) model is able to provide a significant improvement in students' mathematical problem-solving skills compared to direct learning. Before the treatment was given, the researcher carried out *a pretest* on the experimental group and the control group to determine the initial ability of the students to solve mathematical problems. Furthermore, the results of *the pretest* were analyzed using the normality test, homogeneity of variance, and average similarity test. The three tests were used to ensure that the assumptions of normal distribution, uniformity of variance, and whether there were any average differences between the two groups. The entire initial data analysis was done with the help of SPSS software.

Descriptive Analysis

Descriptive analysis was used to obtain an overview of students' mathematical problem-solving abilities before and after being given treatment. The data processed included the calculation of average scores, maximum scores, minimum scores, and standard deviations (SD) in each group (Nasution & Mujib, 2022).

Table 4. Descriptive Statistics of *Pretest* and *Posttest Results*

Groups	Tests	N	Highest Score	Lowest Score	Average
Experimental	*Pretest*	32	50	5	68,30
Experimental	*Posttest*	28	95	25	66,4
Control	*Pretest*	31	25	5	27

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Control	*Posttest*	28	90	20	55,45

Based on Table 4, it can be seen that the average score in the experimental class increased from 20 to 66.4, while the control class increased from 12.4 to 62. These findings indicate that both groups experienced improvements in mathematical problem-solving skills, but the magnitude of the improvement in the experimental class was more pronounced than in the control class.

Initial data analysis

Table 5. Results of the Initial Data Normality Test

Classes	Shapiro-Wilk			Conclusion
	Statistic	**df**	**Sig.**	
Control_ Class	0,968	31	0,516	Normal
Experimental_Class	0,848	31	0,002	Not Normal

Based on Table 5, the results of the *pretest* normality test in the control class showed a significance value of 0.516 which was greater than 0.05, while the experimental class obtained a significance value of 0.002 which was below 0.05. Both results indicate that H_0 is rejected. Thus, at a significance level of 5%, it can be stated that the distribution of *pretest data* from both groups does not meet the assumption of normality.

Table 6. Results of the Initial Data Variance Homogeneity Test

		Levene Statistic	***df1***	***df2***	**Sig.**
Pretest Results	*Based on Mean*	0,000	1	61	0,985

Based on Table 6, the results of *the pretest* homogeneity test in the control and experimental classes showed a significance value of 0.985 which was greater than 0.05. These findings indicate that H_0 is acceptable. Thus, at a significance level of 5%, it can be concluded that the variance of the two groups is homogeneous or has similarities.

Table 7. Average Similarity Test Results

		Sig.	**Remarks**
***Pretest* Scores**	***Mann-Whitney***	0,259	No significant difference

Based on Table 7, a significance value of 0.259 is obtained which is greater than 0.05, so H_0 is accepted. Thus, at a significance level of 5%, it can be concluded that there is no difference in the average mathematical problem-solving ability between the experimental class and the control class at the time of *the pretest*.

Final data analysis

The *posttest results* are used as a basis for the final data analysis. This study aims to assess the effectiveness of learning in two groups, namely the group that received treatment through the Realistic Mathematics Education (RME) model assisted by the GeoSpace application and the group that participated in learning with a direct model. A comparison of the two approaches was carried out to see the extent to which the difference in learning models contributes to the improvement of students' mathematical problem-solving skills.

Table 8. Final Data Normality Test Results

Classes	Say.	Remarks
Control Class	0,168	Normal
Expermental Class	0,057	Normal

Based on the table of normality test results, the significance value of *the posttest* in the control class was 0.168 > 0.05, which indicates that H_0 was accepted. Meanwhile, the significance value of *the posttest* in the experimental class of 0.057 > 0.05, also showed H_0 acceptance. Thus, it can be concluded that the distribution of *posttest data* in both classes meets the assumption of normality at a significance level of 5%.

Table 9. Final Data Variance Homogeneity Test Output Results

		Levene Statistic	***df1***	***df2***	**Sig.**
Posttest Results	*Based on Mean*	0,298	1	54	0,588

The results of the homogeneity test showed a significance value of 0.588 > 0.05, so that H_0 was accepted. This indicates that the variation in the data in the control class and the experimental class is the same or homogeneous. The results of the N-Gain analysis calculated from the comparison of *pretest* and *posttest* scores showed that the control group had an average of 0.30, including the low category, while the experimental group had an average of 0.61, classified as the medium category. These findings indicate a difference in the level of improvement in mathematical problem-solving skills between the two groups. Compared to the group that participated in in-person learning, the group that received treatment through *the Realistic Mathematics Education* (RME) model assisted by *the GeoSpace* application showed a more significant improvement. After obtaining the N-Gain value of each group, the next step is to conduct a statistical test to assess the significance of the difference. If the data met the normality assumption, the analysis continued using *the t-test* for two independent samples.

Table 10. Independent Samples Test Output Results

		Levene's Test for Equality of Variances		**t-test- for Equality of Means**		
		F	*Sig.*	t	Df	*Sig. (2-tailed)*
Posttest Results	*Equal variances assumed*	0,298	0,588	-2,497	54	0,016

Based on the output of *the Independent Samples Test* on SPSS, the *line Equal variances assumed* shows the significance value of Levene's Test of 0.588 (> 0.05), so that the assumption of variance homogeneity is met. Therefore, the interpretation of the t-test uses the *line Equal variances assumed*. The value of sig. (2-tailed) is 0.016. Because the research hypothesis is one-way (right-hand test), the value of sig. One direction is obtained by dividing the value of the sig. (2-tailed) into two, so that a $P\text{-}Value = \frac{1}{2} sig.(2 - tailed) = \frac{1}{2} \times 0{,}016 = 0{,}008$. is obtained With a significance level of $\alpha = 0.05$, the test criteria are to accept H_0 if $p > 0.05$ and reject H_0 if $p \leq 0.05$. Based on the test results, the one-way p-value was $0.008 < 0.05$, so it was rejected. This shows that the mathematical problem-solving ability of students in classes that apply H_0*the Realistic Mathematics Education* (RME) model assisted by *the GeoSpace* application is higher than that of students who participate in direct learning.

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Visualization of results in the form of hisrograms

The histogram in Figure 1 shows the average comparison of *pretest* and *posttest results* between the experimental class and the control class. Visually, it can be seen that both classes experienced an increase in scores from *pretest* to *posttest*, but the increase in the experimental class seemed more significant. The average *posttest* of the experimental class was in a higher range than that of the control class, indicating that the application of the GeoSpace-assisted RME learning model had a stronger influence on the improvement of students' mathematical problem-solving skills. Meanwhile, the control class also showed an increase in value, but the magnitude of the change was not as large as that of the experimental class. This pattern of difference indicates that the learning intervention in the experimental class is more effective than the direct learning applied to the control class.

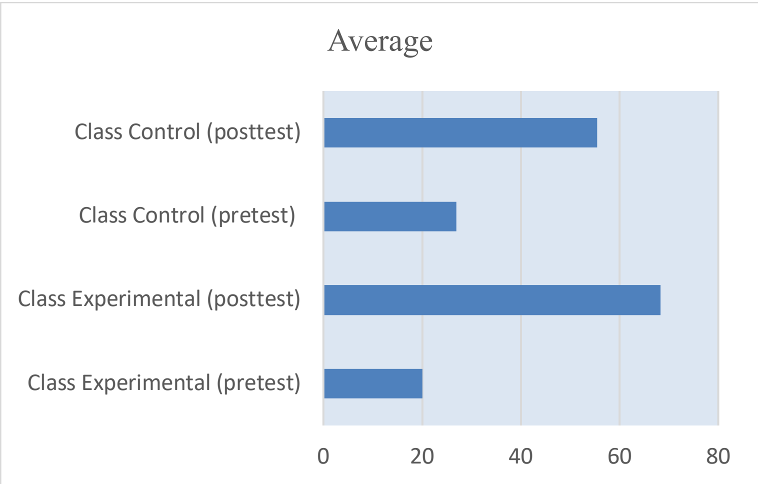

Figure 1. Average Histogram Results *Pretest* and *Posttest*

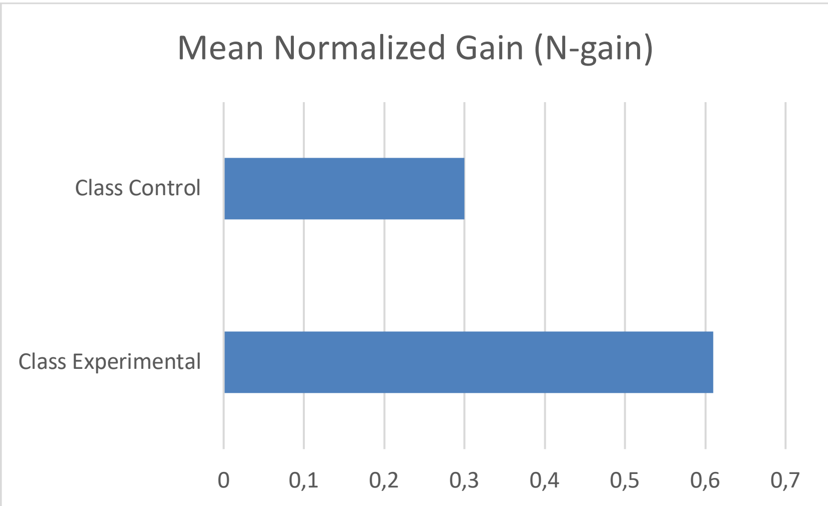

Figure 2. Comparison of N-Gain Values

Figure 2 shows the average *N-Gain ratio* between the experimental class and the control class. Visually, the experimental class showed *an N-Gain* value of about 0.61, while the control class only reached about 0.30. This difference indicates that the improvement in mathematical problem-solving skills in students who participated in the GeoSpace-assisted RME model was greater than in the control class who received hands-on learning. Thus, this visualization reinforces the finding that learning interventions in experimental classrooms provide higher effectiveness in improving problem-solving skills.

Discussion

The results of the study show that the application of the Realistic Mathematics Education (RME) model assisted by the GeoSpace application has a positive effect on improving students' mathematical problem-solving skills when compared to direct learning. The average N-Gain value in the experimental class reached 0.61, classified as medium, while the control class was only 0.30, included in the low category. The t-test of two independent samples showed a significant difference at the level of 5%, with moderate effect sizes (Cohen's d = 0.61; CI 95% [0.14, 1.08]). These results confirm that RME-based learning with GeoSpace-supported learning has a meaningful influence on students' mathematical problem-solving abilities.

Conceptually, the effectiveness of GeoSpace-assisted RME implementation can be explained through the characteristics of the RME model that initiates the learning process from a real context. This approach allows students to actively build knowledge through situations that are meaningful and relevant to everyday experience. In the perspective of constructivistic learning theory, this activity supports junior high school students who are in the transition phase from the concrete operational stage to the formal operational stage in understanding abstract concepts through visual representation and direct experience. Thus, RME and GeoSpace serve as bridges that connect students' real experiences with formal mathematical understanding (Julia et al., 2024; Mandar & Sihono, 2025).

GeoSpace-assisted RME learning stages include three main phases: context exploration, mathematicization (model of to model for), and reflection. In the context exploration stage, students are faced with real problems related to building flat side spaces, such as the design of packaging or the shape of the roof of the house, to give rise to an initial conceptual understanding. Furthermore, at the Nurwahid et al. (2025) horizontal mathematization stage, GeoSpace serves as an interactive medium that allows students to manipulate three-dimensional geometric objects, change viewpoints, and observe the interrelationships between building elements. This activity strengthens spatial thinking skills and problem-solving strategies, as students actively build visual representations and relationships between concepts. In Ayunda Lingga Pranova et al. (2025), the vertical mathematization stage, students express the visual model in a formal symbolic form, such as a broad formula or volume, then review the strategy and its results through reflective discussion (Efendi et al., 2025).

The integration of GeoSpace in the RME model not only serves as a visualization tool, but also functions as an interactive dynamic learning environment that supports independent and collaborative exploration. Features such as adaptive quizzes, contextual practice questions, learning videos, and three-dimensional visualizations allow students to receive direct feedback on their thought processes. This level of interactivity has an important role in the development of reflective skills, spatial thinking, and the interconnectedness between concepts, which are at the core of mathematical problem-solving learning.

The results of this study are consistent with the findings that the RME model is more effective than hands-on learning in improving students' problem-solving skills. The research also emphasizes that integrating digital technology in the RME approach is able to increase students' cognitive engagement and conceptual understanding. In addition, studies by and show that the use of three-dimensional visualization media such as Noviyana & Fitriani (2018), Lestari et al. (2025), Melati et al. (2024) GeoSpace can strengthen students' spatial thinking skills and mathematical connections. These findings are reinforced by the fact that real-world context-based learning can improve high-level thinking skills as well as knowledge transfer

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skills (Lucianinisita & Rahaju, 2020). Practically, the findings of this study provide direction for mathematics teachers to integrate the RME model with digital media such as GeoSpace in the daily learning process. Teachers can use GeoSpace to facilitate the exploration of the concept of building space, help students visualize the relationships between dimensions, and provide a more meaningful and interactive learning experience. This approach also supports the principles of the Independent Curriculum which emphasizes experiential learning, differentiation, and contextual problem-solving (Samho & Princessa, 2025).

Although this study shows a positive influence, there are some empirical limitations that need to be noted. First, the study only involved two classes from one school, so the results could not be generalized widely. Second, even though both classes are taught by the same teacher, the possibility of a teacher effect remains (Suhendra & Ermanto, 2024). Third, the intervention is limited to one topic, namely building a flat-sided space, so its application to other topics still needs to be tested. Therefore, further research is recommended to involve more schools and teacher variations, as well as use a multi-level approach (Adim & Nafi'ah, 2025). Hierarchical Linear Modeling / HLM) or blended design to explore the influence of cognitive and affective factors on the effectiveness of digital media-assisted RMEs. Overall, the findings of this study confirm that the application of GeoSpace-assisted Realistic Mathematics Education (RME) not only significantly improves students' mathematical problem-solving skills, but also strengthens spatial, reflective, and conceptual thinking skills. The integration of digital technologies in contextual approaches such as RME is becoming an important strategy in the development of mathematics learning that is relevant to the demands of the 21st century..

Conclusion

Based on the findings of research and data analysis, it can be concluded that the application *of the Realistic Mathematics Education* (RME) model assisted by *the GeoSpace* application has a positive influence on improving students' mathematical problem-solving skills. Students who participated in RME learning with *GeoSpace*'s support showed a higher increase in problem-solving skills compared to those who participated in hands-on learning. Integrating real context with interactive digital media has proven to be effective in helping students understand mathematical concepts more deeply, increase active engagement, and develop reflective and spatial thinking skills.

The results of the study show that *GeoSpace* does not only function as a visual medium, but also as a means of exploration and mathematicization processes that strengthen the characteristics of RME learning. Through its three-dimensional visualization and interactive features, *GeoSpace* helps students associate concrete experiences with formal representations, thus facilitating the cognitive transition from the concrete operational stage to the formal operational stage. However, this study has some limitations that need to be noted. First, the research sample consisted of only two classes in one school, so the findings obtained could not be generalized widely. Second, the intervention was only carried out on one topic, namely *Building Flat Side Spaces*, so the effectiveness of other mathematics materials needed to be further studied. Third, this study has not accommodated noncognitive factors such as learning motivation, students' perception of technology, and the role of teacher support, which can affect learning outcomes.

Based on these limitations, further research is recommended to involve more schools and classes with diverse characteristics to expand the generalization of the findings. In addition, the use of *a mixed-method* approach is important to obtain a more comprehensive picture of students' thinking processes during RME and GeoSpace-based learning. The development and testing of similar learning media with higher levels of interactivity, including the integration *of* *augmented reality* (AR) or *virtual reality* (VR), also needs to be considered in the context of contextual mathematics learning. Further research also needs to examine the relationship between the use of interactive digital media and students' affective and metacognitive aspects. Practically, the results of this research can be a reference for teachers and curriculum developers in integrating the RME approach with digital media such as GeoSpace in mathematics learning. This approach is in line with the principles of the Independent Curriculum which emphasizes experiential learning and contextual problem-solving, and has the potential to strengthen numeracy literacy while preparing students to face the challenges of 21st century learning

Conflict of Interest

The researcher revealed that there was no conflict interest.

Authors' Contributions

The first author, F.A., was responsible for designing the research, developing the research instruments, conceptualizing the research ideas, collecting data, analyzing and processing the data, and presenting the research results and discussion. The second author, H.U., contributed to revising the manuscript and aligning the overall content of the study. The third author, S., participated in refining the study and discussion and approved the final version of the manuscript. The contribution percentages for conceptualization, preparation, and revision of this article are as follows: F.A.: 60%, H.U.: 20%, and S.: 20%.

Data Availability Statement

The authors declare that the data supporting the findings of this study will be made available by the corresponding author, F.As., upon reasonable request.

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Author Biographies

	**Febi Ayumni** is a student in the Mathematics Education Study Program, Faculty of Teacher Training and Education, Universitas Muria Kudus. She is currently conducting research on a comparison of students' mathematical problem-solving abilities between the GeoSpace-assisted Realistic Mathematics Education (RME) model and the Direct Instruction model. Email: 202135008@std.umk.ac.id

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	**Himmatul Ulya** is a lecturer in the Mathematics Education Study Program, Faculty of Teacher Training and Education, Universitas Muria Kudus. She is currently conducting research on a comparison of students' mathematical problem-solving abilities between the GeoSpace-assisted Realistic Mathematics Education (RME) model and the Direct Instruction model. Email: himmatul.ulya@umk.ac.id
	**Sumaji** is a lecturer in the Mathematics Education Study Program, Faculty of Teacher Training and Education, Universitas Muria Kudus. He is currently conducting research on a comparison of students' mathematical problem-solving abilities between the GeoSpace-assisted Realistic Mathematics Education (RME) model and the Direct Instruction model. Email: sumaji@umk.ac.id