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DEVELOPING VR-ASSISTED RME LEARNING MEDIA TO IMPROVE STUDENTS' CREATIVE THINKING SKILLS IN GEOMETRY

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Abstract

Students' creative thinking in mathematics remains a challenge, particularly in learning three-dimensional geometry. This problem is related to the abstract nature of the material and the limited use of interactive media in classroom instruction. This study aimed to develop and evaluate Virtual Reality (VR)-assisted learning media integrated with the Realistic Mathematics Education (RME) approach to enhance students' creative thinking skills. The study employed a Research and Development design using the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. The participants were 64 ninth-grade students of SMP Negeri 9 Semarang, divided into an experimental group and a control group, with 32 students in each group. Data were obtained through expert validation sheets, student response questionnaires, and a creative thinking test. The findings showed that the developed media met the criteria of high validity, with media expert scores ranging from 92% to 93% and material expert scores ranging from 92% to 96%. Student responses also indicated that the media was practical, with a percentage of 80%. In addition, the experimental group achieved a higher mean score (83.50) than the control group (72.35). The independent samples t-test further revealed a significant difference between the two groups ($p < 0.001$). These results indicate that VR-assisted learning media integrated with the RME approach is valid, practical, and effective in improving students' creative thinking skills.

Keywords: Virtual Reality; Realistic Mathematics Education; Creative Thinking,Three-dimensional Geometry

Abstract

Kemampuan berpikir kreatif siswa dalam pembelajaran matematika masih menjadi tantangan, terutama pada materi geometri tiga dimensi. Kondisi ini berkaitan dengan sifat materi yang abstrak dan belum optimalnya penggunaan media pembelajaran interaktif di kelas. Penelitian ini bertujuan untuk mengembangkan dan mengevaluasi media pembelajaran berbantuan Virtual Reality (VR) yang diintegrasikan dengan pendekatan Realistic Mathematics Education (RME) untuk meningkatkan kemampuan berpikir kreatif siswa. Penelitian ini menggunakan metode Research and Development dengan model ADDIE yang meliputi tahap analysis, design, development, implementation, dan evaluation. Subjek penelitian berjumlah 64 siswa kelas IX SMP Negeri 9 Semarang yang dibagi ke dalam kelas eksperimen dan kelas kontrol, masing-masing sebanyak 32 siswa. Data dikumpulkan melalui lembar validasi ahli, angket respons siswa, dan tes kemampuan berpikir kreatif. Hasil penelitian menunjukkan bahwa media yang dikembangkan memenuhi kriteria sangat valid, dengan skor validasi ahli media sebesar 92%–93% dan ahli materi sebesar 92%–96%. Respons siswa juga menunjukkan bahwa media berada pada kategori praktis dengan persentase 80%. Selain itu, rata-rata skor kelas eksperimen (83,50) lebih tinggi dibandingkan kelas kontrol (72,35). Hasil uji independent samples t-test menunjukkan adanya perbedaan yang signifikan antara kedua kelas ($p < 0,001$). Dengan demikian, media pembelajaran berbantuan VR yang terintegrasi dengan pendekatan RME dinyatakan valid, praktis, dan efektif dalam meningkatkan kemampuan berpikir kreatif siswa.

***Keywords**: Realitas Virtual; Pendidikan Matematika Realistik; Berpikir Kreatif; Geometri Tiga Dimensi*

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INTRODUCTION

Creative thinking is an essential competency in twenty-first-century mathematics education because it enables students to generate ideas, explore different perspectives, and develop meaningful solutions to complex problems (Bintoro et al., 2021). In mathematics learning, this skill is important not only for solving problems procedurally, but also for understanding concepts, connecting ideas, and developing flexible strategies for non-routine problems. Accordingly, developing students' creative thinking skills has become an important goal of mathematics education, in line with the demands of critical thinking, communication, collaboration, and creativity in twenty-first-century learning (Ronny & Mahendra, 2024; Yenti et al., 2022).

However, mathematics learning in schools is still often teacher-centered and emphasizes memorization and procedural accuracy rather than conceptual understanding (Cynthia & Sihotang, 2023). As a result, students' higher-order thinking skills, particularly creative thinking, have not been optimally developed. This issue is more evident in three-dimensional geometry, where students frequently struggle with abstract concepts such as surface area, volume, and spatial relationships that require strong visualization skills (Fathonah & Purnomo, 2025). Although students may apply formulas procedurally, they often have difficulty explaining the underlying concepts or using them flexibly in different situations (Habibie, 2025; Nurfajriyanti & Pradipta, 2021).

Previous studies have shown that creative thinking plays an important role in mathematics learning. Students with stronger creative thinking skills are better able to connect concepts, identify patterns, and propose alternative solutions (Manurung et al., 2023), while creative thinking also strengthens conceptual understanding through diverse strategies and reflective reasoning (Ridwan & Nasrulloh, 2022; Witono & Hadi, 2025). This is consistent with Suherman and Vidákovich (2022), who highlighted mathematical creative thinking as an important construct in mathematics education.

In abstract geometry learning, appropriate media and approaches are needed. Virtual Reality (VR) offers immersive three-dimensional environments that help students visualize and interact with abstract mathematical objects more concretely (Buchori & Pramasdyahsari, 2020). Meanwhile, Realistic Mathematics Education (RME) uses meaningful real-life contexts and encourages students to construct mathematical concepts through exploration, representation, discussion, and progressive reinvention (Nurlatifah et al., 2024).

The state of the art of this study is reflected in previous studies on RME and VR in mathematics learning. Several recent studies have consistently shown that RME has a positive effect on students' mathematical creative thinking. Several studies consistently reported that RME positively contributes to students' mathematical creative thinking. Iskandar and Juandi (2022) concluded that RME improves students' mathematical creative thinking ability. Simamora and Ramadhanta (2024) found that RME resulted in better improvement in mathematical creativity than conventional learning. Similarly, Suciati et al. (2021) reported that realistic mathematics learning improved eighth-

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grade students' mathematical creative thinking, while Syutaridho et al. (2024) found that PMRI significantly affected students' creative thinking ability. In contrast, previous studies on VR have mainly emphasized its contribution to visualization and interactivity in geometry learning (Buchori & Pramasdyahsari, 2020). These findings indicate that RME is strongly related to the improvement of students' creative thinking, whereas VR mainly supports the visualization of abstract geometric concepts and increases student engagement in learning. Overall, these findings suggest that RME supports contextual problem solving and conceptual construction, whereas VR supports visualization and engagement in three-dimensional geometry.

Nevertheless, previous studies still reveal several limitations. Research on RME has mostly focused on conceptual understanding, general learning outcomes, or critical thinking, while studies specifically examining mathematical creative thinking remain limited. Studies on VR have mainly emphasized visualization rather than its integration with contextual approaches such as RME. In addition, empirical studies that systematically integrate VR-assisted learning media with the RME approach using the ADDIE model to improve students' creative thinking skills in three-dimensional geometry are still limited, especially for ninth-grade junior high school students and in relation to the indicators of fluency, flexibility, originality, and elaboration. Therefore, the main research gap lies in the limited empirical evidence on the integrated use of VR-assisted media, the RME approach, and the ADDIE model to improve students' creative thinking skills in three-dimensional geometry.

Based on this gap, the novelty of the present study lies in developing VR-assisted RME learning media using the ADDIE model to improve students' creative thinking skills in three-dimensional geometry. Unlike previous studies that examined VR and RME separately, this study integrates both within a systematic instructional design framework. The conceptual framework of this study is presented in Figure 1.

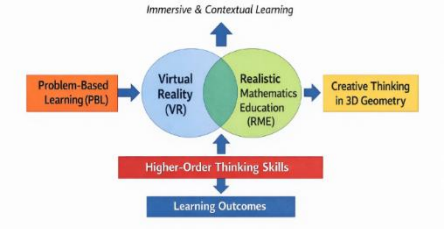

Figure 1 Conceptual framework of VR-assisted RME learning

The problem addressed in this study is that students' creative thinking skills in three-dimensional geometry have not been optimally developed because learning has not provided sufficient opportunities for students to explore ideas, develop multiple strategies, actively construct concepts, and visualize abstract geometric objects meaningfully. As a proposed solution, this study develops VR-assisted RME learning media using the ADDIE model. Accordingly, the objective of this study is to develop VR-assisted RME learning media using the ADDIE model to improve students' creative thinking skills in three-dimensional geometry.

METHODS

This study used a Research and Development (R&D) design with the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation (Branch, 2020; Rusdi et al., 2022). The study was conducted at SMP Negeri 9

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Semarang, Indonesia, during the second semester of the 2025/2026 academic year. The material developed and tested in this study was three-dimensional geometry for Grade IX students.

The participants were 64 Grade IX students, with 32 assigned to the experimental group and 32 to the control group. The sample was selected using purposive sampling because the participants were chosen based on criteria relevant to the research objectives (Etikan et al., 2021). The criteria included relatively similar academic characteristics, prior exposure to prerequisite material, and difficulties in understanding three-dimensional geometry concepts based on preliminary observation. The research site was also selected because the school had adequate facilities, including internet access and digital devices, to support the implementation of VR-assisted learning.

The study procedure followed the five phases of the ADDIE model.

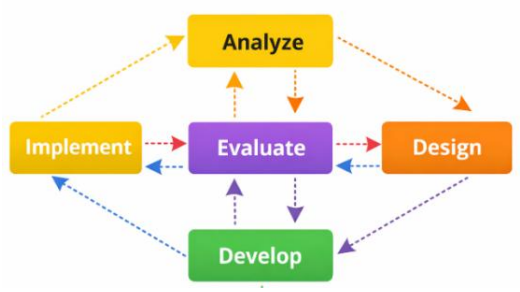

Figure 2. The study procedure followed the five phases of the ADDIE model.

(1) Analysis

At this phase, the researcher examined learning problems, student needs, characteristics of the material, and the availability of supporting facilities. Data were gathered through classroom observations and semi-structured interviews with both teachers and students. The observation focused on learning activities, student participation, teaching methods, and students' difficulties in understanding spatial concepts. The interviews were conducted to obtain information about learning obstacles, students' responses to the learning process, and the school's readiness to implement technology-based learning media.

2. Design

At the design stagethe researcher formulated the learning objectives, arranged the material structure, designed learning activities, and prepared the storyboard of the media. The learning objectives were aligned with the Grade IX mathematics curriculum on three-dimensional geometry and were directed to develop creative thinking skills, including fluency, flexibility, originality, and elaboration. The media was designed to contain concept explanations, contextual problems based on the Realistic Mathematics Education (RME) approach, interactive exercises, and VR simulations of geometric solids such as cubes, prisms, and pyramids.

3. Development

At this stage, the design was transformed into a functional product. The VR environment was developed using Theasys, while the visual learning materials were designed using Canva. The product then underwent expert validation by one mathematics education expert and one media expert. Revisions were made based on the validators' suggestions, especially in terms of visual consistency, clarity of navigation, and media interactivity.

4. Implementation

At the implementation stage, the validated media was applied in classroom instruction. The experimental group learned using VR-assisted learning media integrated with the RME

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approach, while the control group learned through conventional instruction. During the implementation, the teacher acted as a facilitator by guiding students in exploring virtual objects, discussing contextual problems, and constructing mathematical understanding. At the end of the instructional process, students were asked to complete a creative thinking post-test as well as a response questionnaire.

5. Evaluation

In the evaluation phase, the researcher examined the validity, practicality, and effectiveness of the developed media. Validity was measured through expert judgment, practicality was identified from students' responses to the questionnaire, and effectiveness was determined based on the post-test results.

The instruments employed in this study consisted of expert validation sheets, student response questionnaires, and a creative thinking test.

1. Expert Validation Sheets

The expert validation sheets were used to assess the feasibility of the developed media. The media expert validation covered three indicators: (1) media display, (2) content suitability, and (3) product usability. The material expert validation covered three indicators: (1) learning aspect, (2) content quality, and (3) support for creative thinking skills. The validation process was conducted by giving the product and validation sheets to the validators, who then provided quantitative scores and qualitative suggestions for revision.

2. Student Response Questionnaire

The student response questionnaire used a Likert scale to determine the practicality of the developed media after implementation. The questionnaire covered three indicators: (1) general aspects, (2) product feasibility, and (3) ease of learning.

3. Creative Thinking Test

The creative thinking test was given as a post-test to measure the effectiveness of the developed media. The test consisted of structured items representing four indicators of creative thinking, namely fluency, flexibility, originality, and elaboration. Before being administered in the implementation phase, the instrument was tested for validity, reliability, item difficulty, and discrimination index to ensure its suitability for assessing students' creative thinking skills (Widana et al., 2022). Only items that fulfilled the required criteria were included in the final post-test.

Data analysis in this study was carried out systematically in line with the research objectives, which were to identify the needs, validity, practicality, and effectiveness of the developed VR-assisted learning media integrated with the Realistic Mathematics Education (RME) approach. The needs analysis data were obtained through classroom observations and semi-structured interviews with teachers and students. These data were analyzed descriptively to identify instructional problems, students' difficulties in understanding three-dimensional geometry, and the school's readiness to implement technology-based learning media. The findings from this analysis became the basis for determining the specifications of the developed product.

The validity of the developed media was analyzed descriptively using percentage scores obtained from expert validation sheets. The percentages were calculated by comparing the total score obtained with the maximum possible score. Qualitative suggestions from the

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media and material experts were used to revise and improve the product.

The practicality of the media was analyzed descriptively by using percentage scores obtained from the questionnaire of student responses. These scores were used to examine the practicality of the media in terms of general aspects, product feasibility, and ease of learning.

The effectiveness of the media was evaluated through students' post-test scores on creative thinking skills. Before further analysis, the data were tested for normality and homogeneity, and then analyzed using an independent sample t-test. The media was regarded as effective when a statistically significant difference was identified between the experimental and control groups at the 0.05 level of significance.

Through these procedures, the VR-assisted learning media integrated with the RME approach was assessed in terms of validity, practicality, and effectiveness in enhancing students' creative thinking skills in three-dimensional geometry.

RESULTS AND DISCUSSION

This research developed and evaluated VR-assisted mathematics learning media integrated with the Realistic Mathematics Education (RME) approach by applying the ADDIE model. The development process involved five stages: analysis, design, development, implementation, and evaluation. The findings from each stage are described and discussed in the following sections.

a. Analysis

The analysis phase was conducted through classroom observations and interviews involving mathematics teachers and Grade IX students at SMP Negeri 9 Semarang Before conducting the interviews, the researcher prepared an interview guide to obtain information about students' difficulties in learning three-dimensional geometry, the instructional practices used by the teacher, and the need for technology-based learning media.

The results of the observations and interviews were used as the basis for the preliminary study of this research. During mathematics learning activities, it was found that the learning of three-dimensional geometry was still dominated by lecture-based instruction and textbook explanations. Students had difficulty understanding spatial relationships among geometric elements such as faces, edges, and vertices. They also faced challenges in applying formulas for surface area and volume. In addition, students tended to memorize formulas without fully understanding the concepts and their applications. As a result, students' opportunities to develop creative thinking skills in mathematics learning were still limited.

The preliminary findings also showed that the school had adequate technological facilities, including internet access and digital devices, to support technology-based learning. Therefore, these findings became the basis for determining the specifications of the product to be developed, namely VR-assisted learning media integrated with the RME approach to improve students' creative thinking skills in three-dimensional geometry.

b. Design

The design stage was carried out based on the results of the preliminary analysis. At this stage, the researcher formulated the learning objectives, prepared the materials, developed the assessment instruments, and designed the learning media. The objectives were

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aligned with the Grade IX mathematics curriculum on three-dimensional geometry and focused on improving students' creative thinking skills, namely fluency, flexibility, originality, and elaboration..

The developed media integrated Virtual Reality (VR) technology with the Realistic Mathematics Education (RME) approach. VR was used to visualize three-dimensional geometric objects interactively, while RME connected mathematical concepts with meaningful real-life contexts. This design was intended to help students understand abstract concepts more concretely through contextual exploration.

The media design included three main components: learning objectives, learning activities, and media content. The objectives were formulated based on higher-order thinking skills, while the activities were designed by integrating VR and RME principles to create interactive and contextual learning experiences. The content consisted of concept explanations, interactive simulations, and contextual problem-solving tasks arranged through a storyboard and navigation structure.

The media was developed using Theasys for the VR environment and Canva for the visual learning materials. The interface emphasized clarity, consistency, and usability, and the result of this stage was the initial product prototype.

Figure 3 Main page of the VR-assisted learning media

Figure 4 Lesson material page of the VR-assisted learning media

The media was designed using Theasys to develop the VR environment and Canva to prepare the visual learning materials. The interface design emphasized clarity, consistency, and usability so that students could interact with the media easily. As shown in Figure 3, the main page was designed to provide clear navigation and access to the main features of the learning media. Meanwhile, Figure 4 presents the lesson material page, which contains the instructional content prepared to support students' understanding of the topic. The results of this stage became the basis for developing the initial product prototype.

c. Development

After the design stage, the initial product prototype was developed in the form of VR-assisted learning media integrated with the Realistic Mathematics Education (RME) approach for three-dimensional geometry learning. The product was developed using Theasys to create the VR environment and Canva to prepare the visual learning materials. The developed media contained conceptual explanations, interactive simulations, and contextual problem-solving activities designed to support students' creative thinking skills.

After the initial product had been developed, a feasibility test was conducted through expert validation. The developed media was validated in terms of media aspects and material aspects. The media expert validation results can be seen in Table 1.

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Table 1. Initial Product Draft Development

Analysis	Results Analysis	Planning
Research subjects	Students had difficulties in understanding three-dimensional geometry and tended to memorize formulas without conceptual understanding.	Two Grade IX classes with similar academic characteristics were selected as the experimental and control groups.
Instructional condition	Learning was still teacher-centered and provided limited opportunities for students to develop creative thinking skills.	The media was designed to support interactive, contextual, and student-centered learning.
Learning media components	Students needed media that could visualize abstract concepts and connect mathematics to meaningful contexts.	The media integrated VR for visualization and RME for contextual learning.

Acording to the results of the analysis, the product was organized into three main parts. The opening section contained the media identity and navigation. The main section contained concept explanations, VR simulations, and contextual learning activities based on the RME approach. The final section contained exercises and evaluation tasks designed to assess students' creative thinking skills in three-dimensional geometry.

After the initial product had been developed, a feasibility test was conducted through expert validation.

The developed media was assessed based on two main aspects, namely media and material. The media aspect was evaluated to determine the feasibility of the product in terms of appearance, content suitability, and usability, while the material aspect was evaluated to determine the appropriateness of the content, learning suitability, and support for students' creative thinking skills. The results of each validation are presented in Table 2 and Table 3.

Table 2. Results of Media Expert Validation

Validator	**Aspect**	**Total Score**	**Maximum Score**	**Percentage**	**Eligibility**
I	Product appearance	28	30	93 %	Highly Feasible
	Content suitability	19	20	95 %	
	Product usage	27	30	90 %	
II	Product appearance	28	30	93 %	Highly Feasible
	Content suitability	18	20	90 %	
	Product usage	28	30	93 %	

Based on Table 2, the media validation results ranged from 90% to 95%, with mean scores of 92.6% from Validator I and 92.0% from Validator II. These findings indicate that the developed media was highly feasible for classroom implementation. The high scores suggest that the media was considered clear, relevant, and easy to use in learning activities. However, minor revisions were still needed, particularly in improving the clarity of teacher instructions and adding background music to create a more enjoyable

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learning atmosphere. These improvements were intended to strengthen the practicality and effectiveness of the media in classroom use.

Table 3. Result of Material Expert Validation

Validator	Aspect	Total Score	Maximum Score	Percentage	Eligibility
I	Learning	24	25	96 %	Highly Feasible
	Content Quality	38	40	95 %	
	Creative Thinking Support	19	20	95 %	
II	Learning	23	25	92%	Highly Feasible
	Content Quality	38	40	95 %	
	Creative Thinking Support	19	20	95 %	

Based on Table 3, the material validation results showed percentage scores ranging from 92% to 96%, indicating that the developed media was highly feasible in terms of learning appropriateness, content quality, and support for students' creative thinking skills. These high scores suggest that the material was well aligned with the learning objectives, clearly presented, and relevant to promoting students' active and creative engagement in mathematics learning. This may be explained by the systematic organization of the content, the clarity of the presentation, and the integration of activities that support students' exploration of ideas and problem-solving strategies. Following the validation process, the media was revised based on the validators' suggestions by improving the structure of the learning content, visual clarity, display consistency, and navigation of the virtual reality interface. These revisions were made to strengthen both the pedagogical quality and practical usability of the media.

These revisions were intended to make the media more attractive, easier to use, and more supportive of students' understanding of three-dimensional geometry concepts. The revised product is presented in Figure 5 and Figure 6.

Figure 5. Revised learning content with improved structure and visual clarity.

The revised learning content after improvements in material organization and visual presentation. The content was arranged more systematically to make it easier for students to understand the concepts.

Figure 6. Revised virtual reality interface with enhanced navigation and usability.

The virtual reality interface was revised to improve navigation and usability, making the media easier to

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use in classroom learning. These revisions were necessary to ensure that students could interact with the media more effectively. Furthermore, the analysis of learning outcomes and learning objectives provided the basis for developing content that was aligned with the curriculum and focused on students' creative thinking skills in three-dimensional geometry. The results of this analysis are presented in Table 4

Table 4. Analysis of Learning Achievements and Learning Objectives

Element	Achievements	Objectives
Geometry (Three-Dimensional Geometry)	1. Students are able to identify the elements of three-dimensional shapes and understand their spatial relationships.	1. Students are able to explore the elements and spatial relationships of three-dimensional shapes through VR-assisted learning.
	2. Students are able to determine the surface area and volume of three-dimensional shapes.	2. Students are able to determine the surface area and volume of three-dimensional shapes correctly.
	3. Students are able to use geometric concepts to solve contextual problems related to everyday situations.	3. Students are able to solve contextual problems related to three-dimensional geometry using the RME approach.

After the initial product prototype had been developed, a feasibility test was conducted through expert validation and a limited-scale trial. The product was validated by experts to determine its appropriateness in terms of media and material aspects. After the validation process, several revisions were made to improve the product before it was tested in classroom learning. Following the expert validation, a limited-scale trial was conducted to identify the strengths and weaknesses of the developed media. Students' responses to the VR-assisted learning media integrated with the RME approach were collected through a questionnaire. The assessed aspects included general aspects, product feasibility, and ease of learning. The results of the student response questionnaire are presented in Table 5.

Table 5. Results of the Student Response Questionnaire

No	Aspect	Score Obtained	Maximum Score	Eligibility Percentage (%)
1	General aspects	593	750	80%
2	Product feasibility aspects	803	1000	
3	Ease of learning aspects	614	750	
	Total	2010	2500	

Based on Table 5, the student response questionnaire showed positive results in all assessed aspects. The general aspect reached 79.07%, the product feasibility aspect 80.3%, and the ease of learning aspect 81.9%. The overall percentage was 80.4%, indicating that the VR-assisted learning media integrated with the RME approach was positively received by students. These findings suggest that the media was considered feasible, useful, and relatively easy to use in supporting learning activities.

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d. Implementation

The implementation phase involved a large-scale trial with two groups of ninth-grade students at SMP Negeri 9 Semarang, namely an experimental group and a control group, each consisting of 32 students. The experimental group learned using VR-assisted learning media integrated with the RME approach, while the control group received conventional teacher-centered instruction. This phase aimed to examine the effectiveness of the developed media in improving students' creative thinking skills in three-dimensional geometry.

Before being used, the creative thinking test instrument was analyzed for validity, reliability, item difficulty, and discrimination index, and the results showed that it was suitable for assessment. During the implementation, students in the experimental group learned through virtual representations and contextual problems, whereas students in the control group learned through verbal explanation and textbook-based exercises without interactive media.

1) Prerequisite Test

(a) Normality Test

The normality test was conducted using the Shapiro–Wilk test. The results showed that the significance values for the control class (9F) and the experimental class (9G) were 0.011 and 0.002, respectively. Since both values were lower than 0.05, the data in both groups were not normally distributed. Therefore, the independent samples t-test was not appropriate.

Because the data were not normally distributed, the hypothesis was tested using the Mann–Whitney U test. The result showed an Asymp. Sig. (2-tailed) value of 0.032, which was lower than 0.05. This indicates that there was a significant difference in students' creative thinking skills between the control class and the experimental class.

(b) Homogeneity Test

The homogeneity test was conducted using Levene's test. The result of the test is presented in Table 6.

Table 6. Homogeneity Test Result

Levene Statistics	df1	df2	Sig.
3.926	1	62	0.52

Based on Table 6, the data were homogeneous because the significance value was 0.052 > 0.05. However, the normality test showed that both groups were not normally distributed, with significance values of 0.011 for class 9F and 0.002 for class 9G. Therefore, the data were analyzed using the Mann–Whitney U test instead of the independent samples t-test.

2) Testing the Effectiveness of the Developed Media

The effectiveness of the developed VR-assisted learning media integrated with the Realistic Mathematics Education (RME) approach was tested by comparing the post-test results of the experimental and control groups. Since the normality test showed that the data in both groups were not normally distributed, the hypothesis testing was conducted using the Mann–Whitney U test as a non-parametric alternative.

Table 7. Group Statistics

Class	**N**	**Mean**	**SD**
Class F	32	83.50	7.36
Class G	32	72.34	10.09

The descriptive statistics showed that the experimental group obtained a mean score of 83.50 with a standard deviation of 7.36, while the control group obtained a mean score of 72.34 with a standard deviation of 10.09.

The result of the Mann–Whitney U Test Result is presented in Table 8.

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Table 8. Mann–Whitney U Test Result

Statistic	Value
Mann–Whitney U	223.500
Wilcoxon W	751.500
Z	-3.895
Asymp. Sig. (2-tailed)	0.032

Based on Table 8, the Mann–Whitney U test showed an Asymp. Sig. (2-tailed) value of 0.032, which was lower than 0.05. This indicates that there was a significant difference between the post-test scores of the two groups. Thus, the findings support the hypothesis that the developed VR-assisted learning media integrated with the Realistic Mathematics Education (RME) approach was effective in improving students' creative thinking skills in three-dimensional geometry.

This result is not only statistically significant, but also pedagogically meaningful. The higher achievement of the experimental group suggests that the integration of VR and RME provided a more meaningful learning experience than conventional instruction. VR helped students visualize and explore three-dimensional objects more clearly, while the RME approach supported them in understanding mathematical ideas through meaningful and contextual activities. As a result, students were more actively involved in learning, better able to construct understanding, and more encouraged to develop their creative thinking skills.

Several factors may explain this outcome. First, the immersive and interactive nature of VR made abstract spatial concepts easier to understand. Second, the RME approach encouraged students to learn through contextual exploration and problem solving. Third, the combination of interactive technology and meaningful learning contexts likely increased students' engagement and participation during the learning process. These factors together may explain the better performance of the experimental group.

These findings support the hypothesis that the developed VR-assisted learning media integrated with the RME approach was effective in improving students' creative thinking skills in three-dimensional geometry (Amahsyah et al. (2025),. This result suggests that VR helped students visualize abstract spatial concepts more clearly, while RME supported them in understanding mathematics through meaningful and contextual activities (Ningsih et al., 2024; Nursyahidah et al., 2025).. As a result, students were more actively involved in learning and better able to develop creative thinking skills. This finding is consistent with previous studies showing that VR can improve motivation and learning performance in geometry (Huang et al., 2022), that RME contributes positively to mathematical creativity (Jupri et al., 2024), and that mathematical creative thinking is an important focus in mathematics education (Suherman & Vidákovich, 2022).

This study also showed strengths in terms of validity, practicality, and effectiveness. Expert validation indicated that the media was highly feasible, and student responses showed that it was practical and easy to use in classroom learning. These findings suggest that the developed product was not only effective in improving students' creative thinking skills, but also appropriate for classroom implementation.

However, this study had several limitations. It focused only on one topic, namely three-dimensional geometry, and involved only Grade IX students in one school. In addition, the

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implementation of VR-assisted learning requires adequate technological facilities, which may limit its use in schools with limited resources. Therefore, the findings should be interpreted within the context of this study.

Despite these limitations, this study contributes to mathematics education both practically and theoretically. The developed media can be used as an alternative for teaching abstract mathematical topics, while the findings also show that integrating immersive technology and contextual learning can support students' creative thinking skills. Future research is recommended to apply the media to other topics and broader learning contexts.

CONCLUSIONS

This study concludes that the developed VR-assisted learning media integrated with the Realistic Mathematics Education (RME) approach is valid, practical, and effective in improving students' creative thinking skills in three-dimensional geometry. The main findings showed that the media was highly feasible based on expert validation, received positive responses from students, and showed a significant difference in post-test results between the two groups. These findings indicate that the developed media can be used as an alternative to support more interactive and meaningful mathematics learning.

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