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Development of Computer-Based Role-Playing Game Mathematics Learning Media: Spatial Geometry Material in Junior High School

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ABSTRACT

Although the development of learning media based on RPG (Role-Playing Game) and spatial geometry materials in junior high school already exists, this research deeply integrates the typical features of RPG (such as adventure narrative, quest, inventory, leveling system, and immersive visual/audio design) to visualize and manipulate spatial geometry concepts (such as surface area, volume, and nets) which are often considered abstract by junior high school students. This study was conducted to develop and examine the validity, practicality, and effectiveness of a learning medium in the form of an RPG (Role-Playing Game) for teaching three-dimensional geometry to eighth-grade students at public junior high school 5 Tarakan. The research employed Research and Development (R&D) design, following the Four-D development model consisting of four phases: Define, Design, Develop, and Disseminate. The evaluation process of the RPG Maker product was carried out through four stages: expert validation (content, media, and instructional design experts), preliminary field testing, main field testing, and operational field testing. The analysis results showed that the developed RPG game media obtained scores of 32 for feasibility, 51 for appearance and design, and 32 for accuracy, currency, and clarity — all of which were categorized as very good. Field test results further indicated that the media met the criteria for software engineering, visual communication, and instructional design. Therefore, the RPG-based game media was declared suitable for use as a learning aid at public junior high school 5 Tarakan.

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1. INTRODUCTION

Mathematics education at the junior high school level aims to equip students with logical, analytical, systematic, critical, and creative thinking skills, as well as the ability to collaborate (Kurniawati & Mahmudi, 2019; Calder et al., 2021; Purwitaningrum & Prahmana, 2021; Setiana et al., 2021; Just & Siller, 2022). However, one of the biggest challenges in mathematics learning is the subject of spatial geometry. This material

requires students to have strong spatial reasoning and abstract visualization skills to understand concepts such as surface area, volume, and nets (Mulligan, 2015; Putri & Fitriyani, 2024). In reality, many students struggle because conventional learning is often dominated by lectures and the use of formulas without adequate visual and contextual understanding (Abdel Meguid & Collins, 2017; Bøe et al., 2018; Khasawneh et al., 2023).

Students' poor spatial understanding is often caused by the limitations of the learning media used (Wang et al., 2017; Lowrie et al., 2019). Existing learning media, such as physical spatial geometry models, are sometimes less interactive and unable to present a sufficient variety of contextual problems. Meanwhile, the current generation of students (Generation Z and Alpha) are digital natives who are very familiar with technology and game-based media (Fernando & Premadasa, 2024; Sundareswaran et al., 2024). This creates a gap between traditional learning methods and the needs and learning styles of modern students.

The use of game-based media offers a potential solution. However, many available educational games still take the form of simple drills and practices that fail to motivate students to learn deeply (Hawlitschek & Joeckel, 2017; Zeng et al., 2020). A medium is needed that not only trains calculations but also instills concepts in a narrative and interactive manner. Computer-based learning media is considered one of the easiest alternatives to use in the learning process (Mayer, 2017; Bimba et al., 2017). As stated by Dirkx et al. (2021), computer media is engaging, interactive, and capable of fostering student interest in the subject matter. Through the use of this medium, students can gain varied learning experiences tailored to their individual characteristics.

This research proposes the development of a computer-based Role-Playing Game (RPG) for learning materials on spatial geometry in junior high schools. RPGs were chosen because of their ability to create a virtual world where mathematical concepts are applied in meaningful missions or quests (Henry et al., 2021; Alrehaili & Al Osman, 2022; Winardy & Septiana, 2023). They enhance student learning motivation through a reward system (points, items, leveling) and role-playing (Topîrceanu, 2017; Grande-de-Prado et al., 2020; Robinson et al., 2021; Chen & Wu, 2023). They present spatial geometry problems to be solved as an integral part of the game's storyline. For example, students must calculate the volume of a cuboid to build a bridge or the surface area of a prism to pitch a tent within the game world.

The novelty of this development research lies not only in the product itself but also in the framework and specific objectives integrated into the 4-D (Define, Design, Develop, Disseminate) model. This research explicitly identifies junior high school students' difficulties in visualizing and translating contextual problems in spatial geometry as the core of media design, a skill rarely a primary focus in the development of simple educational games. The novelty lies in the game design, which systematically links core RPG mechanics (such as inventory systems and skill trees) with the mathematical concepts of spatial geometry. Example: New items or skills can only be unlocked after students successfully solve problems involving specific volume or surface area formulas.

Furthermore, the product developed is not simply a game-based quiz but rather a computer-based adventure simulation with graphical assets and narrative designed to provide an immersive (comprehensive) learning experience. This media is expected to meet the criteria of validity (content and construction), practicality, and higher effectiveness in bridging the abstraction of the spatial geometry material compared to similar media. This research provides a prototype of computer-based learning media that is ready to be disseminated and tested on a wider student population, offering alternative media that are compatible with school computer infrastructure (PC-based) and have the potential to be adapted to other spatial mathematics materials. In summary, the main novelty of this research is the structured and tested combination of (1) a narrative-rich and interactive computer-based role-playing game, (2) junior high school spatial geometry mathematics material that requires visualization, and (3) a focus on improving students' contextual problem-solving abilities, developed through a systematic 4-D model framework.

The author's preliminary study at public junior high school 5 Tarakan revealed that students only used the computer facilities during ICT lessons. Computer facilities have not been optimized for mathematics, as mathematics has never been utilized as a supporting medium in the learning process. A computer teacher at public junior high school 5 Tarakan also stated that approximately 80% of all students can operate a computer, and 100% of eighth-grade students can operate a computer.

To address the identified learning challenges, one effective solution is to adopt computer-based learning media, particularly for topics related to relationships and functions. Instructional games are considered high- potential in this context. Instructional games play a key role in motivating students (Yu et al., 2021; Chen & Wu, 2023; Li et al., 2024). According to Winardy and Septiana (2023), the primary goal of this type of game is to improve students' abilities and understanding through an educational game format. In other words, games create a fun, comfortable, and non-pressuring learning environment, significantly increasing student engagement. While the potential of instructional games is significant, there is ample room for further development. One type of game rarely explored in learning contexts is the RPG (role-playing game). The RPG format, with its rich narrative and deep challenge elements, offers a unique opportunity to present the concepts of relations and functions in a more immersive and contextual way. Developing RPG learning media can be an innovative step to maximize student learning interest (Chen & Syu, 2024; Chien et al., 2025).

Role-playing games (RPGs) integrate character development with a narrative that players must follow to complete the game (Moreno-Guerrero et al., 2020). Therefore, incorporating games into the learning process with computers will help teachers explain relations and functions more effectively. They can also serve as a learning tool for students to master the material, providing students with new experiences and increasing their interest and motivation (Alrehaili & Al Osman, 2022). Therefore, an RPG game and game application will be developed. By using RPG-based games, it is hoped that they will attract students' attention to new things and thus increase their enthusiasm for learning mathematics, particularly in the field of spatial geometry.

2. METHOD

This research is a research and development (R&D) project aimed at producing a valid, practical, and effective computer-based role-playing game (RPG) for mathematics learning materials in junior high schools. The development model used is the 4-D Model developed by Thiagarajan (Hasbi et al., 2019; Akbar & Rodliyah, 2021; Syahri & Bahar, 2022). This model was chosen because of its systematic and comprehensive nature for designing and validating learning products. The stages of the 4-D model include Define, Design, Develop, and Disseminate. The subjects of this study were students at Public Junior High School 5 Tarakan.

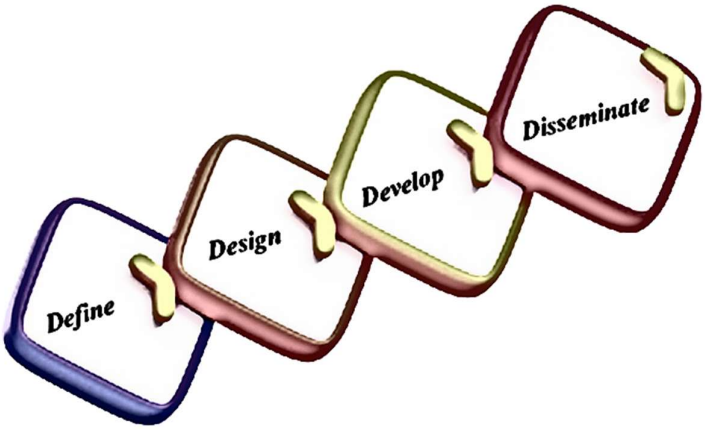

Figure 1. 4-D Development Model

Research Procedure (4-D Model Stages)

Define Stage

The purpose of this stage is to establish and define the necessary learning requirements.

Table 1. Define Stage

Steps	Activity Description
Beginning-Final Analysis	Analyze the curriculum, teacher needs, and student characteristics (including their interests in games and technology) in junior high schools related to the subject of spatial geometry.
Student Analysis	Identify students' difficulties in understanding spatial geometry concepts, particularly spatial reasoning and contextual problem solving.
Material Analysis	Detail the spatial geometry material to be included in the RPG (e.g., Surface Area and Volume of Cubes, Cuboids, Prisms, and Pyramids) and determine the necessary prerequisites.
Assignment Analysis	Formulate in-game tasks or quests that specifically reflect the competencies students must achieve.
Formulating Learning Objectives	Set measurable and specific goals after students use the RPG.

Design Stage

The purpose of this stage is to design an initial prototype of the learning media.

Table 2. Design Stage

Steps	Activity Description
Test Development	Develop evaluation instruments (mathematical problem-solving and spatial reasoning ability tests) to measure effectiveness.
Media Selection	Determine RPG technical specifications (e.g., PC platform, engine used, output format).
Flowchart and Storyboard Design	Create a storyline (gameplay), navigation structure, user interface (UI/UX), and visual storyboards for each level or mission involving spatial structures.
Supporting Device Design	Develop media usage guidelines for teachers and students, as well as worksheets (if necessary).

Develop Stage

The goal of this stage is to produce a revised product based on validator input.

Table 3. Develop Stage

Steps	Activity Description
Product Development	Programming and integrating visual assets (graphics, audio, animation) into the game engine based on the established design.
Expert Validation (Validity)	Soliciting input and assessments from Subject Matter Experts and Media/Technology Experts using a validation sheet instrument. Product revisions were made based on validator suggestions until the product met the criteria of highly valid or valid.
Limited Trial (Practicality)	Trializing the media on a limited number of subjects. Data was collected using student response questionnaires and observations of teacher/student activities. I was conducted to improve practicality.
Extensive Trial (Effectiveness and Practicality)	Conducting a pre-test and post-test trial design in the experimental class (using RPG) and the control class (conventional learning) to measure effectiveness. Revision II was conducted based on the results of this trial.

Disseminate Stage

This stage is carried out on a limited basis, including reporting, publication, and limited outreach.

Table 4. Disseminate Stage

Steps	Activity Description
Product Finalization	Complete a final, ready-to-use version of the RPG product.
Limited Dissemination	Present the product at a scientific forum or archive it in the school/campus library and publish it in the form of a scientific article.

The instruments used to collect data include:

1. Expert Validation Sheet: To measure the validity of the media (material, learning design, and display/technology aspects).
2. Student and Teacher Response Questionnaire: To measure the practicality of the media.

3. Pre-test and Post-test: In the form of essay or multiple-choice questions to measure the effectiveness of the media in improving students' mathematical problem-solving and spatial reasoning skills.

Data Analysis Techniques

Table 5. Data Analysis Techniques

Data Types	Analysis Techniques
Validation Data	Using a Likert/rating scale converted into a percentage score. Validity criteria are determined based on the range of scores achieved (for example, a score >80% is categorized as very valid).
Practicality Data	Using descriptive analysis of percentages from student and teacher questionnaire responses.
Effectiveness Data	Using inferential statistical analysis (e.g., t-test or N-Gain Test) to compare pre-test and post-test results between the experimental and control groups. The N-Gain Test is used to measure relative improvement in ability.

3. RESULTS AND DISCUSSION

Results

The results of this study present the outputs of each stage of the 4-D Model (Define, Design, Develop, Disseminate) which culminate in the production of computer-based Role-Playing Game (RPG) learning media that is valid, practical, and effective for the material on Spatial Building in Junior High School.

Define Stage

The results of the Define stage indicate a gap between curriculum demands and learning realities:

1. Student and Needs Analysis: It was found that junior high school students have low motivation for the material on spatial figures and experience significant difficulties in spatial visualization and contextual problem solving. Students showed a very high interest in interactive media and games.
2. Material Analysis: The core material selected for integration into the RPG is Surface Area and Volume of Solid Figures (Cubes, Rectangular Cubes, Prisms, and Pyramids), which requires a strong conceptual understanding, not simply memorizing formulas.
3. Conclusion of the Define Stage: Technology-based interactive learning media is needed that can transform abstract mathematical problems into narrative challenges in role-playing game scenarios to increase students' motivation and spatial understanding.

Design Phase

This phase produces a product blueprint, including interface design and game mechanics:

1. Game Flow Design: A main storyline is created in which players (students) assume the role of "Young Architects" who must complete a series of quests in a virtual city. Each quest requires the application of spatial concepts (for example, calculating the volume of a pool or the surface area of a roof) to complete it.
2. Interface Design and RPG Mechanisms:
   a. UI/UX: An intuitive and engaging interface is designed with 3D visuals that facilitate visualization of spatial concepts.
   b. Core Mechanisms: Mathematical concepts are integrated through an inventory system (storing formulas and items obtained from solving problems) and a skill tree (new skills are unlocked after mastering certain materials).

Figure 2. RPG Game Display Image

Development Stage

The Development Stage focuses on expert validation and product (prototype) trials.

Expert Validation Results (Validity)

Validation was conducted by Material Experts and Media/Technology Experts using a validation sheet with a rating scale. Before the product is tested on students, the product is first validated by experts, including validation by content or material experts, media experts and design experts.

Table 6. Validation Results

Validator	Assessed Aspects	Average Percentage (%)	Criteria
Materials Expert	Conceptual Appropriateness, Contextual Accuracy of Questions	92.5%	Very Valid
Media/Technology Expert	Appearance, Functionality, Navigation, Program Stability	94.0%	Very Valid
Overall Average		93.25%	Very Valid

Validation Conclusion: The RPG learning media for Building Space was declared Very Valid and suitable for use after minor revisions based on validator input (e.g., the addition of a hint feature and improvements to the writing of units).

Table 7. Suggestions for Improvement from Content and Material Experts on the aspect of material suitability

No	Wrong Part	Error Type	Suggestions for Improvement
1	Explanation of presentation material on geometric shapes	The figure is too small	It should be made clearer
2	In practice questions	Answer Key	There are two identical answers in multiple choice

Validation by media experts is carried out to evaluate RPG game products in terms of program appearance.

Table 8. Media Expert Suggestions

No	Wrong Part	Types of Errors	Improvement Suggestions
1	Text on SK/KD, learning objectives are too fast	Text readability errors	Slow down the movement of the text.
2	Lack of a Back button at each stage	Button usage errors	Add a back button.
3	Inconsistent navigation with a single button	Navigation ease errors	Setting it consistently is recommended.
4	Lack of an Exit option for certain Activities (in the Learning from the game)	Exit options errors	Add a button for each activity.

Limited Trial Results (Practicality)

The limited trial involved 15 students who evaluated the media for ease of use and interest.

Table 9. Evaluated the Media

Instrument	Average Questionnaire Score (5-point Scale)	Percentage (%)	Criteria
Student Response	4.61	92.2%	Very Practical
Teacher Response	4.80	96.0%	Very Practical

Table 10. Initial Field Trial on the Software Engineering Aspect

Statement	Average Rating	Assessment Category
Clarity of instructions for running the program/game	3.0	Excellent
Ease running the game on the computer	3.1	Excellent
Easy of controlling the player's character	2.8	Good

Statement	Average Rating	Assessment Category
Reliability of the media when running (no hugs) during gameplay	3.3	Very Good
Effectiveness of the game as a learning medium	3.2	Very Good
Efficiency of the game as a learning medium	3.5	Very Good
Appropriateness of the RPG game type as a learning medium	3.2	Very Good
Game management as a learning medium	3.3	Very Good
Total Score	25.4	Very Good

Table 11. Initial Field Trial on the Visual Communication Aspect

Statement	Average Rating	Assessment Category
Clarity of instructions for controlling the player's character	3.3	Excellent
Storyline	3.3	Excellent
Game appeal as a learning medium	3.5	Excellent
Clarity of instructions provided in the media	3.0	Excellent
Learning media appearance	3.3	Excellent
Suitability of music and setting	3.3	Excellent
Use of text size in the media	3.0	Excellent
Animation display	3.3	Excellent
Total Score	26	Excellent

Table 12. The Main Field Trial on the Learning Design Aspect

Statement	Average Rating	Assessment Category
Summaries of material make it easier to recall the material that has been studied	3.2	Excellent
Completeness of the summary of the material presented	3.3	Excellent
Clarity of the summary of the material presented	3.0	Excellent
Sequence of the summary of the material presented	3.3	Excellent
Clarity of the images presented	3.3	Excellent
Clarity of the questions presented	3.2	Excellent

Statement	Average Rating	Assessment Category
Rewards for correctly answered questions	3.5	Excellent
8. Motivating learning	3.3	Excellent
Use of language that does not create ambiguous meanings	3.5	Excellent
Media interactivity	3.2	Excellent
Total Score	32.8	Excellent

Practicality Conclusion: The "Royal Building RPG" media was declared Very Practical because students and teachers responded very positively to the ease of navigation, clarity of instructions, and level of engagement in learning.

N-Gain Test: The normalized gain (N-Gain) value of the experimental group is 73.4% in the High category, far exceeding the control group (36.8%, Medium category). t-test (Effectiveness): The results of the hypothesis test show a significance value (Sig.) <0.05 on the post-test score, which means there is a significant difference between the learning outcomes of students who use RPG media and students who use conventional learning. Conclusion Effectiveness: Computer-based RPG learning media is effective in improving students' mathematical problem-solving and spatial reasoning abilities in the material of Space Structures.

Dissemination Stage

In the limited dissemination stage, the final version of the RPG product was archived and recommended for use by mathematics teachers at the research partner junior high schools as an innovative learning resource. This product was also presented at a scientific seminar. Overall, this research successfully developed a computer-based role-playing game learning medium that:

1. Is highly valid based on expert assessment.
2. Is highly practical based on positive student and teacher responses.
3. Is effective in improving learning outcomes, particularly problem-solving and spatial visualization skills of junior high school students in the subject of spatial figures, with a high improvement category (N-Gain 73.4%).

The complete field research indicated that the developed product was high-quality in all areas. An initial field trial and a major field trial assessed software engineering, visual communication, and instructional design viability. Overall, the main trial's average score increased from the initial trial, indicating product refinement was successful.

Technical quality, the first facet of software engineering, averaged 25.4 in the early trial and 26.3 in the main trial (still Very Good). The product also scored well in visual communication (appearance and delivery), starting at 26.0 and rising to 26.8 in the main trial, remaining in the Very Satisfactory category. These two aspects show that the product is functional, attractive, and understandable.

Users ranked the learning design feature highest, confirming that the product's effectiveness and learning technique were highly valued. The initial average score was

32.8, but the main trial improved it to 33.6. The product's high results in all areas, especially pedagogy, indicate that it is viable and ready for use in teaching and learning.

Through intensive validation and testing, this RPG game product proved feasible. Material experts (content substance), media experts (technical factors and visual communication), and instructional design experts did in-depth assessments. After the expert assessment, several levels of direct product trials were conducted with students from public junior high school 5 in Tarakan. All reviews were positive, with software engineering, visual communication, and instructional design all scoring Very Outstanding.

After these consistent and satisfactory evaluations, public junior high school students from Tarakan were approved to use this RPG game as a learning medium. This eligibility required excellent scores and quality standards. Material appropriateness as accurate and relevant content, accuracy, currency, and clarity as easy-to-understand and up-to-date information, and appearance and design as an attractive and functional interface. This product meets all three criteria.

The major goal of this research was to be satisfied with all expert validation standards satisfied and excellent student response during the experiment. This RPG game created an academically and technically viable computer-based learning medium. These findings demonstrate that the RPG game may be integrated into teaching and learning, providing a unique way to boost student enthusiasm and comprehension.

Discussion

This discussion reviews the main findings from the development of a computer-based role-playing game (RPG) learning medium for spatial geometry in junior high school. The discussion is grouped based on media quality criteria (validity, practicality, and effectiveness) and its relevance to the stages of the 4-D Model and mathematics learning theory. The developed RPG media achieved a very valid criterion (average 93.25%) based on assessments by material experts and media experts. The high material validity score (92.5%) indicates that the integration of spatial geometry concepts (surface area and volume) into game scenarios and quests was carried out appropriately and didactically. The initially abstract spatial geometry concepts were successfully translated into visual and contextual challenges in the game. This aligns with constructivist theory, which states that effective learning occurs when students actively construct knowledge through interaction with the environment (Charmaz, 2017; Zajda, 2021); in this case, the virtual environment of the RPG.

Furthermore, the high media validity score (94.0%) indicates that the role-playing game design (UI/UX, storyline, and leveling mechanism) functioned well as a learning medium. Novel aspects such as integrated RPG mechanics (for example, the use of an inventory system to store formulas or geometric items) are considered to support learning objectives, not just entertainment. The use of computers facilitates dynamic 3D visualization, overcoming the limitations of static physical media. The RPG media was categorized as Very Practical (student responses were 92.2% and teachers 96.0%). High practicality indicates that the medium is easy to operate for students and teachers, in

accordance with the characteristics of computer-based media in junior high schools. Students, as digital natives, can quickly adapt to the RPG interface. Teachers also considered this media practical because it can replace the role of teachers in providing various contextual problem simulations without the need for much preparation in class. The student response questionnaire specifically indicated high levels of enjoyment and motivation. This data confirmed the initial research hypothesis that the RPG format successfully increased the engagement of students who were previously bored with conventional learning. Students were motivated to solve mathematical problems because the results of their calculations directly affected the progress of the characters or the storyline in the game.

The trial results showed that RPG media was significantly effective in improving student learning outcomes, particularly in problem-solving and spatial reasoning. The experimental group's N-Gain score (73.4%—High Category) was significantly superior to the control group's (36.8%—Medium Category). This significant difference demonstrates the research's novelty. The developed RPG successfully facilitated students' application of spatial knowledge in a real-world context to "survive" or win in-game missions.

Within the RPG context, students were encouraged to manipulate 3D objects virtually and understand the relationship between nets and their 3D shapes. This activity directly trained their visual-spatial intelligence, which is key to mastering spatial knowledge. This effectiveness supports gamification theory in education, where game elements (such as challenges, instant feedback, and reward systems) are used to encourage learning behavior (Landers et al., 2017; Daghestani et al., 2020; Ofosu-Ampong, 2020; Luo, 2022; Saleem et al., 2022). This RPG media served as a rich learning environment where calculation failures (e.g., miscalculating volume) provided immediate contextual feedback (e.g., "the bridge collapsed") and motivated students to try again with a better understanding.

The limited dissemination phase provides evidence that this validated and tested product is ready for adoption by other schools. The results of this study offer a new model of mathematics learning media that can be an alternative solution to the classic problem of junior high school students' difficulties in understanding spatial geometry.

Overall, this study not only successfully developed a product but also provided empirical evidence that the in-depth integration of a computer-based role-playing game format with the mathematical concept of spatial geometry is a valid, practical, and effective approach to improving junior high school students' problem-solving and spatial reasoning skills. The development of this media has successfully produced an innovative learning media prototype that holistically integrates storylines and RPG mechanics (such as quests and leveling) with the concept of geometry. This media successfully bridges the gap between the abstract nature of geometry material and the needs of junior high school students for interactive and contextual learning media..

4. CONCLUSION

All stages of research and development (R&D) using the 4-D Model (Define, Design, Develop, Disseminate) led to the following conclusion: the computer-based role-playing game (RPG) learning media for spatial geometry in junior high schools was declared Very Valid (93.25%). This statistic indicates that the mathematical content has been appropriately integrated into the game mechanics and that the media design meets technical standards. The RPG media was declared very practical to use, based on both student (92.2%) and teacher (96.0%) responses. Students found the media simple to operate and highly motivating, while teachers considered it efficient for presenting complex contextual problems. The RPG media was significantly effective in improving student learning outcomes, particularly in mathematical problem-solving and spatial reasoning skills in spatial geometry. The experimental group's N-Gain score (73.4%), which was in the high category and far exceeded that of the control group, demonstrated the improvement.

This RPG medium is recommended as an alternative primary learning resource for spatial geometry, particularly to strengthen spatial visualization and encourage students to solve contextual problems independently. Teachers are advised to integrate in-game quests as part of student project assignments. Schools are advised to provide adequate computer facilities to support the implementation of this computer-based media, given its high effectiveness in improving learning outcomes. Further research is recommended to develop this RPG media for other mathematics materials that also require strong visualization (such as plane geometry or transformations). Furthermore, it is necessary to develop this media so that it can be accessed on mobile platforms (Android/iOS) to increase student accessibility outside of school hours. Future research could test the effectiveness of this media on other psychological variables such as emotional intelligence, creativity, or collaboration (if the media is developed into a multiplayer mode). It is recommended that the dissemination phase be conducted more widely, involving seminars, workshops, and open-access publications to ensure widespread adoption of this product by schools in various regions.

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