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Development of RPG Maker-Based Games to Enhance Students' Mathematical Connections

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Abstract: Mathematics learning in schools often requires innovative approaches to make abstract concepts more concrete and engaging for students. In particular, digital game-based learning has emerged as an effective strategy for increasing motivation and deepening conceptual understanding. Mathematical connection is an important competency for understanding the relationships among mathematical ideas, concepts, and procedures; however, most students still struggle to apply this ability, especially when solving geometry problems. This research aims to develop learning media in the form of a game using RPG Maker to enhance students' mathematical connection abilities in geometric transformations. The educational game learning media was designed and developed using the ADDIE development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. Instruments included expert validation sheets, student response questionnaires, and pretest-posttest assessments to measure media validity, practicality, and effectiveness. The results show that the RPG Maker-based learning media is highly valid, with an average expert validation score of 87.0% from media experts and 86.0% from material experts. Students also rated the media as very practical, with an average score of 84.2%. Learning improvement from this media is evident in the increase in the average student score from 70.14 on the pretest to 89.17 on the posttest. Furthermore, the non-parametric Wilcoxon test confirmed a statistically significant difference ($Z = -5.25$, $p < .001$). This improvement is also supported by a large effect size ($d = 3.63$) and an average N-Gain of 0.57, which falls into the moderate category. These findings indicate that the RPG Maker-based learning media is valid, practical, and holds potential to enhance students' mathematical connection skills in geometry transformation learning, offering an engaging solution for abstract mathematical learning.

Keywords: mathematical connections, geometric transformations, learning media, RPG maker, ADDIE model.

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INTRODUCTION

Learning mathematics is crucial because it is a science that examines concepts, methods, and related ideas (Dewi & Nurjanah, 2022). Understanding the connections between mathematical ideas, concepts, and procedures is known as mathematical connection (Diana et al., 2020), which is beneficial in everyday life (Purnomo et al., 2024). Furthermore, mathematical connection is a collection of ideas that can be used to demonstrate principles and correlations related to mathematics (Jawad, 2022), and plays a crucial role in various social and educational contexts because it can build a good understanding of mathematics for both learners and educators (Rodríguez-Nieto et al., 2025). As a result, mathematical connection is a fundamental ability to include in the mathematics curriculum.

National curricula in many countries emphasize mathematical connections, including the United States (Leinwarnd, 2014), Australia

(Xu et al., 2023), and Indonesia (Kurikulum Merdeka). This is because mathematical connections play an important role in helping students understand the relationships between mathematical concepts and various fields of knowledge (Asfar et al., 2022; Habsyi & Saleh, 2022). In addition, mathematical connections can enhance the usefulness of mathematics learning for students (Sholeha et al., 2022; Caviedes et al., 2024), serve as a tool that enables problem-solving (García-García & Dolores-Flores, 2021; Nabilah et al., 2024), and can assess the extent of their understanding of mathematical concepts (Nisa & Dewanti, 2023). Therefore, mathematical connections should serve as a facilitator across every mathematics topic, including geometry.

Geometry is one of the most important fields in mathematics, allowing rich connections with other mathematical topics such as algebra and calculus (Buchori et al., 2024). In line with this view, mathematical connections help students understand relationships between geometric concepts, such as shapes and properties (Mastuti et al., 2023). This relationship is essential in the topic of geometric transformations. When students learn about geometric transformations, they can make connections between geometric concepts, for instance, between shapes and coordinates (Usdinoari & Julie, 2023). Additionally, understanding how a shape changes using geometric transformations can help students connect geometric properties such as congruence and algebraic concepts (Usdinoari & Julie, 2023). Consequently, students should embrace mathematical connections when learning geometric transformations.

Nevertheless, many studies indicate that students still struggle to establish these connections, as shown by their inability to link various mathematical concepts (Septian, 2022; Son, 2022). Similarly, students' ability to connect mathematical concepts when solving a problem remains relatively low (Andriani et al., 2025; Apriani et al., 2024). These problems were also showed on one of the high schools in Bandung, West Java. Based on the interview conducted at this high school, the results indicate that students often struggle to visualize and connect mathematical concepts, especially in geometric transformations. This problem occurs because students view geometry as a difficult subject, so they still struggle to recognize and understand geometric shapes (Alghadari et al., 2020). Therefore, geometry learning must be adjusted with mathematical connection aspects and the use of media.

To help students overcome these difficulties in learning geometry, they need media that develop their mathematical connection skills. Among these media, teachers might use educational games that can increase students' interest and enthusiasm in the learning process (Applebaum, 2025). Educational games are a form of digital technology in mathematics education that can clarify the presentation of concepts, thereby providing a more interactive and engaging learning experience for students (Cirneanu & Moldoveanu, 2024). Role-playing games are one type of game that may be able to enhance students' motivation and mathematical connections. According to Fardian et al (2024), the integration of Role-Playing Games Maker (RPGM) has been proven to enhance students' interest and motivation. Meanwhile, Pramuditya et al. (2025) found that using RPG Maker games in higher mathematics problems helps most students apply mathematical concepts in their daily lives.

Various studies have highlighted the importance of mathematical connection skills and the effectiveness of games in learning (Fardian et al., 2024; McMullen et al, 2023; Pramuditya et al., 2025). However, few studies focus on developing educational games specifically designed to enhance students' mathematical

connection skills in the context of geometric transformations. Therefore, this research aims to fill that gap by developing an RPG Maker-based game specifically designed to enhance mathematical connection skills in the context of geometric transformations and to examine its effectiveness in learning. To achieve this objective, this study addresses three specific research questions:

RQ1: What is the validity of the RPG Maker-based learning media?
RQ2: What is the practicality of the RPG Maker-based learning media?
RQ3: What is the potential effectiveness of the RPG Maker-based learning media in enhancing students' mathematical connection skills?

METHOD

Research Design

This research used the ADDIE (analyze, design, develop, implementation, and evaluation) model. The ADDIE model is a classic instructional design model with five main stages: analysis, design, development, implementation, and evaluation (Lai et al., 2023). This model has been widely used in various fields, particularly in developing learning and training programs, because of its systematic and flexible approach (Deng et al., 2023). In accordance with that, the ADDIE model was used in this study because it is highly relevant in the development of educational products because it includes clear steps, goal aligned with the needs of learners, measurable and valid evaluations, flexible general stages, development based on empirical data, and practical learning applications to establish that educational products can meet effective learning needs (Spatioti et al., 2022). Based on these advantages, this model was used to develop RPG games for the geometric transformation topic. The development of the game-based learning media followed the ADDIE model, which includes five stages: Analysis, Design, Development, Implementation, and Evaluation. Each phase involved specific activities, instruments, and expected outcomes to ensure that the media aligned with instructional goals and addressed learners' needs.

Participants

This research was conducted at a private high school in Bandung. For product validation, four expert validators evaluated the learning media: one university lecturer specializing in instructional media, one university lecturer specializing in mathematics content, and two senior high school mathematics teachers with over 10 years of teaching experience. The practicality test was conducted with thirty-six twelfth-grade students who had already studied the topic and their mathematics teachers. Meanwhile, the media effectiveness testing involved thirty-six eleventh-grade students selected through cluster random sampling. The selection procedure involved randomly selecting one class from four eleventh-grade classes. Since all clusters initially consisted of thirty-six students, all individuals within the selected class were included as the sample. Prior to data collection, written informed consent forms were distributed to all participating students to ensure voluntary participation and data confidentiality.

Instrument Data Collection

The instrument for data collection was constructed to measure the validity, practicality, and effectiveness of the developed RPG Maker-based games. Expert validation sheets were used to measure the validity of the learning media, while questionnaires for teachers and students were used to determine practicality when using the RPG Maker game. Unstructured interviews with students and teachers were also conducted to confirm and deepen the questionnaire findings.

Finally, pre-test and post-test questions were used to evaluate effectiveness in improving students' mathematical connection skills. The questions consisted of three essay questions designed according to the mathematical connection indicators in Nendi et al. (2023): the connection of mathematics between topics in mathematics, the connection of mathematics with other disciplines, and the connection with everyday life. Prior to their use, these instruments underwent validity and reliability testing. Theoretical validities were verified by expert judgment, while empirical validity was confirmed using Product-Moment correlation, with all items yielding valid results. Furthermore, the questions were tested on 36 students to ensure reliability. The reliability of the research instrument was assessed using internal consistency analysis. The test yielded a Cronbach's alpha coefficient of 0.824. According to Taber (2018), Cronbach's alpha values above 0.80 represent robust internal consistency for cognitive research instruments. This confirmed that the assessment items were highly reliable for measuring students' mathematical connection skills.

Data Analysis Procedure

This study employed quantitative analyses to evaluate the validity, practicality, and potential effectiveness of the developed RPG-based learning media in enhancing students' mathematical connection abilities. Validity data from expert judgment and practicality data from student and teacher questionnaires were analyzed by calculating the percentage score as the total empirical score divided by the maximum possible score. The percentage scores from the four expert validators were analyzed descriptively to establish expert consensus and guide product revisions. These percentage scores were then categorized based on validity and practicality criteria. The validity and practicality criteria for the learning media, adapted from Winarni et al. (2022), are as follows in Table 1.

Table 1. Validity and feasibility criteria

Percentage (%)	Category	Description
0% – 20%	Not Valid	Cannot be used
21% – 40%	Less Valid	Requires major revision
41% – 60%	Fairly Valid	Valid, can be used with moderate revision
61% – 80%	Valid	Valid, but needs minor revision
81% – 100%	Highly Valid	Highly valid, no revision needed

To evaluate the media's potential effectiveness in enhancing students' mathematical connection skills, pretest and posttest scores were analyzed using both descriptive and inferential statistics. Descriptive statistic was processed using the normalized gain (N-gain) score and analyzed using the N-gain criteria based on (Hake, 2010), as presented in Table 2.

Furthermore, to confirm whether score gains were statistically significant, a paired-samples t-test was conducted after ensuring data normality using the Shapiro-Wilk test on the pre-test and post-test score differences. The magnitude of improvement in mathematical connection abilities was evaluated using Cohen's effect size, categorized according to Cohen (2013) as shown in Table 3.

Table 2. N-Gain criteria

Normalized Gain Value (g)	Criteria
$0.70 \leq g \leq 1.00$	High
$0.30 \leq g < 0.70$	Medium
$0.00 \leq g < 0.30$	Low

Table 3. Effect size category

Effect Size (d)	Category
$0.80 \leq d$	Large
$0.50 \leq d < 0.80$	Medium
$0.20 \leq d < 0.50$	Small

These statistical analyses capture the progression of students' mathematical connection skills within a single-group framework and provide preliminary evidence of the media's instructional potential.

■ RESULT AND DISCUSSION

Analysis Stage

The analysis stage was conducted through observations of students' learning activities at a private high school in Bandung, as well as interviews with the 11th-grade mathematics teacher. Based on the observation results, students experienced challenges in understanding geometric transformations, especially in connecting these concepts with other mathematical concepts. This result aligns with Alghadari et al. (2020), who found that students have difficulty connecting basic geometry concepts with other concepts they already know. Interviews with teachers showed that the teaching approach used is direct learning and less utilizes interactive media. This resulted in low learning motivation and underdeveloped mathematical connection skills among the students. The same problem was identified in Apriani et al. (2024): mathematics is often taught as a collection of unconnected concepts. Moreover, Apriani et al. (2024) stated that learning models or learning methods are essential for improving mathematical connection. Therefore, learning media is needed to integrate geometric transformation material with real-world contexts in an engaging and interactive manner.

Design Stage

The design of digital game-based learning media using RPG Maker was based on the results of a needs analysis. The learning objectives focused on enhancing students' mathematical connection skills by understanding geometric transformations (translation and dilation) through other mathematics materials, other science materials, and real-life contexts. To meet these objectives, storyboards were designed to define the screen layouts, audio elements, and interactive mechanics, as shown in Figure 1 below.

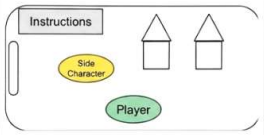
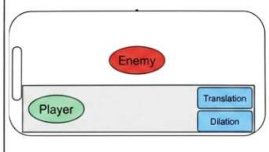
Visual	Sketch	Audio
Menu display with a village background image		Music with village ambiance
In-game world display set in the village background		Peaceful ambiance music
Battle display against enemy with multiple action options		Spirited ambiance music

Figure 1. Storyboard

A rural-themed interface and peaceful background audio were selected for the main menu and exploration maps to create a comfortable learning environment, as Yu et al. (2022) stated that music in games may help the young generation learn something new.

Furthermore, a battle system was implemented to adapt abstract problem-solving into a fast-paced battle where geometric transformation serves as a tool to defeat enemies. Furthermore, initial drafts of expert validation sheets and user acceptance test instruments were prepared.

Development Stage

The next stage was the development phase, which consisted of game development and game testing. Game development comprised creating game instruments, determining visual designs tailored to learners' needs, and creating learning instruction within the game (Johnson & van Allen, 2026). Development was carried out using RPG Maker software, which was then converted into an Android application using HTML for Android. Figure 2 (Results) below shows the development process.

During the software authoring process in the RPG Maker engine, the development focused on configuring event scripts, map properties, and

Figure 2. Game development

database parameters. Maps were built using tilesets to create the rural exploration environment, while custom Event Commands were set up to handle NPC interactions and transitions into battle scenes. Here are the results of the game design that was developed:

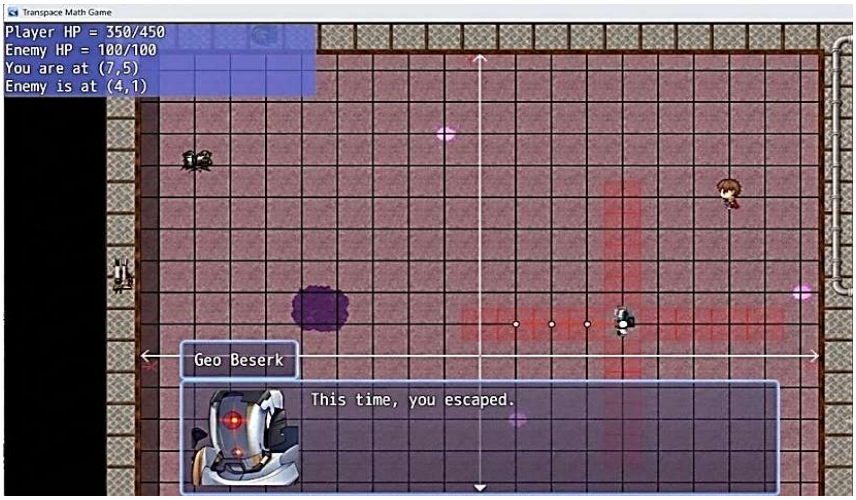


Figure 3. Geometry transformation page

Figure 1 above is the page for geometric transformations, where translation and dilation are conducted in a battle format. Students could input the desired translation or dilation vector according to the battle conditions. Students had the freedom to determine the transformation vector, which can enhance their independence and creativity. Students understood the randomly generated battle conditions at each turn before determining the transformation vector.

Implement Stage

The next stage was material validation, media validation, and UAT (User Acceptance Test). The material and media validation was conducted by four expert validators: two university lecturers and two senior high school mathematics teachers. The UAT results showed that the game's appearance is good. Users faced several issues, namely difficult character movement, informal language usage, and poorly understood concept explanations. The game was then revised to eliminate these issues and validated to assess the suitability of the mathematics content.

Table 3. Material validation results

Aspect	Average Percentage
Achieved Competencies	86.7%
Content Coverage	88.0%
Material Presentation	86.0%
Mathematical Connection	86.7%
Language Use	85.6%
Overall	86.0%

Expert validation confirmed the pedagogical alignment of this learning media in translating abstract mathematical concepts into engaging challenges. Geometric transformation topics, particularly transformation composition, were integrated into interactive role-playing game activities. The game allows students to explore and prove these concepts by experiencing them, solving problems in relatable contexts without the cognitive load of conventional instruction. The refinements based on validator feedback focused primarily on ensuring proper mathematical symbols, such as vector and coordinate notations. Consequently, the validated material provides a structured learning environment that helps students connect abstract geometric concepts with practical contexts, supporting the development of mathematical connection skills. In addition to content validation, the game will also be validated by media aspects such as software design, media design, visual communication, and operational instructions. The media validation results are shown in Table 4 below.

Table 4. Media validation results

Aspect	Average Percentage
Software	87.5%
Operational Instructions	87.5%
Media Design	84.0%
Visual Communication	86.0%
Overall	87.0%

Based on Table 4, the media validation results indicated that the game's design met the highly valid criteria. The validation process also yielded several comments and suggestions, particularly regarding a lack of in-game instructions. Therefore, the summative evaluation process was carried out based on these improvement suggestions from both the UAT and validation stages. The students conducted the feasibility assessment, and 36 respondents gave an overall score of 84.28%; this finding means the game was ready to be implemented in the learning process. The game was implemented in a geometric transformation course at one of the private schools in Bandung, West Java. The following Figure 4, Game Operation, is documentation of the game operation by the students:

Figure 4. Game operation

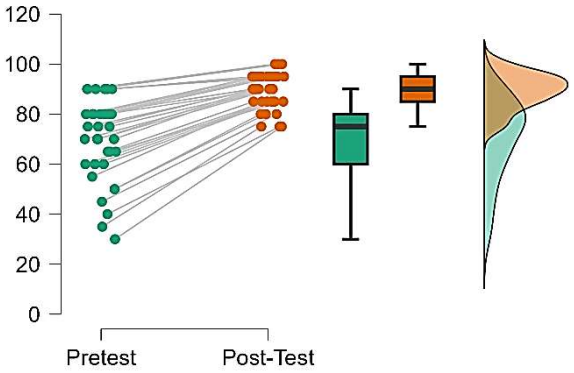


Figure 5. Raincloud plot of pre-test and posttest result

Students were then asked to gather the necessary information from the game to solve the problems in the worksheet. Through this learning process, students solved mathematical connection problems based on the information obtained from the game. This finding resonates with the results observed in Applebaum's (2025) study, which demonstrated that the game significantly enhanced students' mathematical understanding. Finally, students are directed to complete a post-test, which serves as a data-collection instrument to evaluate the product's potential effectiveness.

Evaluation Stage

Pretest and post-test evaluations were conducted with students to measure the game's potential effectiveness. The pretest was conducted by giving students three essay questions formulated based on indicators to measure mathematical connection skills. The Post-Test was then conducted with students who had already used the RPG Maker game, using four questions of the same type as the pre-test. Figure 5 shows a graph of the students' pre-test and post-test scores, showing improvement in each individual's score.

The graph in Figure 5 showed that students' mathematical connection was improved significantly as a result of integrating the RPG-Maker game media into the learning process. In terms of mathematical connection skills, the average pre-test score before using the RPG-Maker game was 70.14. After implementing the game, the average post-test score increased to 89.17, with an improvement score of 19.03 points. Each student made remarkable progress in their mathematical connection skills, as confirmed by an N-Gain score of 0.57, which categorized the improvement as fairly effective.

To evaluate the product's effectiveness, a pretest and posttest were administered. The normality test on the gain scores using the Shapiro-Wilk test indicated that the data were not normally distributed ($W = 0.92$, $p = 0.015$). Consequently, the non-parametric Wilcoxon Signed-Ranks test was employed. The results revealed a statistically significant difference between pretest and posttest scores ($Z = -5.25$, $p < 0.001$). Furthermore, the calculated effect size was $d = 3.63$, indicating that the implemented game had a strong positive effect on students' learning outcomes.

As shown in Figure 6, all three indicators improved following the intervention. Indicator 1, which measures inter-mathematical concepts, increased from 75.55% to 89.85%. Indicator 2, interdisciplinary connection, rose from 67.87% to 89.63%. Meanwhile, Indicator 3 regarding real-life contexts showed the most significant growth, leaping from 58.33% to 85.63%. These results align with Sager et al. (2023), who found that educational games encourage learners to explore mathematical concepts embedded in their surroundings.

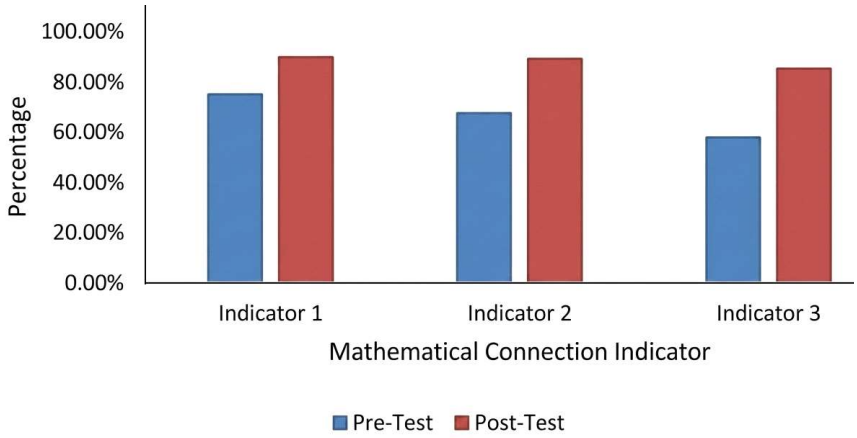


Figure 6. Average score percentage

While Indicator 1 established a high initial baseline, Indicator 2 also improved. Visual representation and in-game feedback enabled students to connect geometric transformations with interdisciplinary tasks such as velocity. The exploration of mathematics educational games, particularly RPG Maker games, highlights that learning media can provide more interactive ways to explain mathematical concepts. Students feel motivated to understand a concept so they can proceed to the next stage of the game. Septian's (2022) study also highlights that applying learning media positively impacts motivation and activity. Moreover, the game activities demonstrate how geometric transformations such as translation and dilation affect a point's coordinates. This is in line with Nindiasari et al.'s (2024) study that learning media can demonstrate the application of a particular mathematical concept, allowing students to observe it mre deeply. Figure 6 below shows the step-by-step demonstration of the gometric transformation concept within the game.

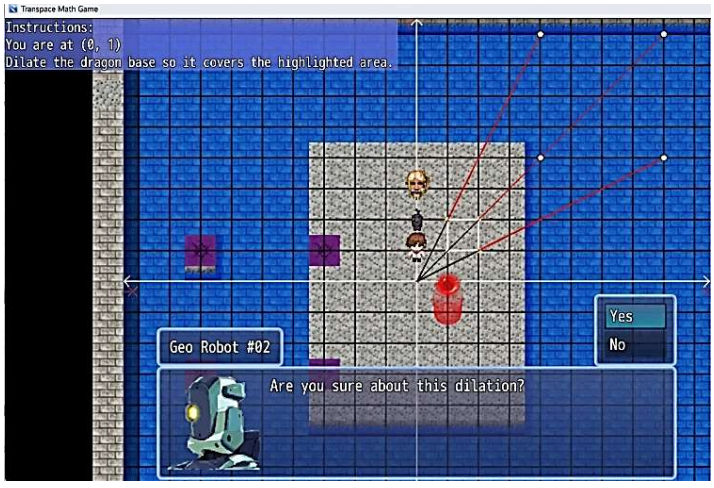


Figure 7. Game geometric transformation

Additionally, game activities in this study give students context for applying prior knowledge such as arithmetic operations and Cartesian coordinates. Applying prior knowledge may improve mathematical connection skills. As Son (2022) stated, the main principles of connecting mathematical concepts are prior knowledge that functions as a bridge to the target knowledge. The creativity aspect of the game also enhanced the student's mathematical connection. This is

because the RPG Maker game in this study gives students the freedom to determine the answer, choose the correct character skills, and evaluate the outcome. Fardian et al (2024) emphasize several benefits of role-playing games, as students, as players, have control over the development of their characters and strategic decisions.

However, it is important to consider the difficulties students experience during gameplay. Based on unstructured interviews conducted with students after the implementation of role-playing games, they faced challenges due to a fast-paced battle system that required them to think and calculate vectors precisely under a time limit. In contrast, a study by Asfar et al. (2022) showed that solving problems faster can improve understanding of mathematical concepts, which relates to mathematical connection. This study indicated that some of the game problems represents student's development of mathematical skills, especially mathematical connection. Moreover, students faced a challenge because of the randomness of enemy movement; they were able to observe the pattern and then find the right answer. Cantillo-Rudas et al. (2024) stated that students with mathematical connections tend to solve problems by observing patterns. Furthermore, students were able to solve the problem because they could build connections between prior knowledge and other mathematical concepts present in this game. This finding confirms the study, namely García & Flores (2021) and Nabilah et al. (2024), which assert that mathematical connection functions as a tool for solving mathematical problems.

Therefore, integrating RPG-maker games affected the key aspect of mathematical connection skills. Role-playing games present mathematical concepts interactively, engaging students to solve problems. The games also illustrated the use of prior knowledge in geometric transformation problem resulting in students make connection across mathematical topics. The battle format included in this game stimulates quick thinking and pattern recognition, which impacts mathematical connection skills. Based on these findings, RPG-maker based game have significant potential to enhance mathematical connection abilities.

CONCLUSION

Based on the results of the study, it can be concluded that the development of RPG Maker-based games on the geometric transformation topic was completed following the ADDIE stages, even though it still requires improvement. The game is valid and feasible through the development process. Furthermore, a statistically significant improvement between the pretest and posttest scores demonstrated the game's potential to support student learning within the tested group. In addition, the use of RPG maker engaging student's motivation and creativity. Thus, to improve students' mathematical connection skills, it is recommended to implement the RPG Maker-based game in mathematics learning.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing of this manuscript, translation tools and built-in proofreading software, such as Google Translate and Microsoft Editor, were employed solely for English translation, grammar checking, and identifying typographical errors. The authors independently developed and verified all conceptualization, analysis, and scholarly content.

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