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Development of Android-Based Game Media in Improving Students' Mathematical Literacy

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ABSTRACT

This research aims to develop an Android-based learning media to enhance junior high school students' mathematical literacy, particularly in understanding numbers. It employs a development research approach with a qualitative methodology supported by quantitative data. The research follows the Research and Development (R&D) method, adapted from the Plomp model. The innovation involves the creation of a game-based learning media using an Android platform. The game itself is a web-based application developed through Wordwall. The study's subjects consist of 26 seventh-grade students, selected from MTs GUPPI Sukamoro in Banyuasin Regency and Srijaya Negara Junior High School in Palembang City. The data collection techniques used in this study included: (1) a validation sheet to assess the validity of the game product, (2) a student response questionnaire consisting of 11 questions to assess the practicality of the game, (3) pretest and posttest to assess students' mathematical literacy, and (4) interviews conducted if issues arose after the game and test were administered. Data analysis was carried out using quantitative methods. The validity and practicality levels of the data are analyzed using percentages, while the test data is evaluated based on the N-gain value. The results indicated that the Android-based game achieved a validity score of 77.54%, categorized as good. The data test results were 0.65 and 0.58, falling within the moderate criteria. Additionally, the classical average scores were 96.1% and 100%, with students achieving an average score of 84.69 and 83.88. These findings demonstrate that the Android-based learning media is both valid and effective in enhancing mathematical literacy on number concepts among seventh-grade students.

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A. INTRODUCTION

Mathematical literacy refers to an individual's ability to formulate, apply, and interpret mathematics in various real-life contexts (Mboeik, 2023). This competency is essential for problem-solving and informed decision-making, enabling individuals to engage in society constructively and reflectively (Lindawati, 2018). Mathematical literacy empowers individuals to tackle real-world challenges effectively, making it a crucial skill in today's rapidly evolving world (Manfreda Kolar & Hodnik, 2021). The essential elements of mathematical literacy include capturing ideas, solving problems, communicating information, and applying mathematical systems (Mansah & Safitri, 2022).

In a broader sense, literacy is a fundamental right and a key driver of sustainable development. UNESCO's "Literacy for All" initiative highlights literacy's transformative impact, ranging from poverty reduction and improved health outcomes to gender equality and

democratic participation (UNESCO, 2016). Beyond reading and writing, literacy now encompasses digital skills, critical thinking, and the ability to navigate an increasingly technology-driven world (Liambela, 2024). Despite global efforts to improve literacy, disparities persist, with a significant portion of the population still lacking access to quality education (Malina-Urbanz, 2024). Moreover, as societal changes accelerate, critical reading and analytical skills become even more vital for fostering informed social participation and decision-making. Since the 1990 Jomtien Conference, global literacy policies have evolved, yet challenges remain, necessitating sustained efforts at both local and international levels (Liambela, 2024); Malina-Urbanz, 2024).

Within the educational context, research indicates that students often struggle with mathematical literacy, particularly in tasks requiring critical and logical thinking (Genc & Erbas, 2020). While many students can extract information from problems, they frequently encounter difficulties in evaluating solutions and applying mathematical concepts to real-world scenarios. Muslimah & Pujiastuti (Muslimah & Pujiastuti, 2020) supports this finding, stating that students with higher mathematical literacy levels are more likely to solve problems accurately, whereas those with lower literacy levels have a significantly reduced success rate. These findings underscore the need for innovative educational strategies to enhance mathematical literacy and problem-solving abilities.

One promising approach is the integration of Information and Communication Technology (ICT) in education. In the 21st century, ICT literacy—which includes internet literacy, computer literacy, and information literacy—has become indispensable for both students and educators (Santos et al., 2019). Factors such as parental and teacher support, the use of the internet as an educational tool, and the availability of digital resources play a significant role in student learning. However, despite rapid technological advancements, many schools still underutilize ICT in teaching and learning (Muyaroah & Fajartia, 2017). Traditional textbooks, for instance, can be transformed into more engaging digital resources, making lessons more interactive and improving students' comprehension. The effective integration of ICT into education has been shown to enhance both learning experiences and overall student engagement (Kim et al., 2014; Lau & Yuen, 2014). Given these benefits, developing innovative educational media is crucial in improving students' numeracy literacy from elementary to high school (Zainudin & Fatah, 2023).

The role of technology in education is particularly evident in the growing use of mobile devices and digital platforms. Mobile phones, which were once used primarily for communication, now serve as powerful educational tools (Criollo-c et al., 2021). Frilia et al. (2020) found that Android-based learning media significantly enhances students' ability to solve mathematical problems, highlighting the potential of mobile applications in education. As technological advancements continue to shape learning environments, educators must adapt by leveraging digital tools to facilitate meaningful learning experiences (Masykur et al., 2017). The development of interactive and engaging learning media is essential to ensuring that students not only grasp mathematical concepts but also develop problem-solving skills in alignment with modern technological advancements (Herwindo et al., 2025).

One of the most effective methods for integrating technology into education is throughеducational games (Aini & Ayu, 2019). Research has shown that game-based learning

enhances students' understanding of mathematical concepts while increasing engagement and motivation (Adrillian & Aini, 2023). Educational games provide an interactive platform where students can develop numeracy skills more enjoyably and effectively (Zeng et al., 2019). Further emphasizes the benefits of game-based learning for children with disabilities, as it helps improve focus and makes learning more accessible (Saputro et al., 2018). However, despite the advantages of educational games, their integration into formal education remains limited (Gallud et al., 2023). Many teachers continue to rely on conventional teaching methods, which may not fully engage students in the learning process (Venera & Nicolae, 2020).

One potential solution is the use of Wordwall, a web-based game-based learning platform that offers various interactive quizzes and activities. Research suggests that game-based learning can be measured through key indicators such as student engagement, critical thinking, participation, attention, and enthusiasm for learning (Hartt et al., 2020). However, the effectiveness of platforms like Wordwall depends on the types of mathematical problems being addressed (Istiqomah, 2024). Moreover, cognitive differences among students affect their ability to benefit from game-based learning. For example, Sari and Wulan (2024) found that students with a field-dependent cognitive style excel in mathematical literacy primarily when they are required to break down and analyze information. Nonetheless, educational games remain an invaluable tool in online learning, helping students build foundational mathematical knowledge while enhancing their problem-solving abilities (Hidayat et al., 2024).

This study aims to develop an Android-based educational game as an interactive learning medium to support mathematics education. The goal is to create valid, practical, and beneficial teaching materials that align with technological advancements and improve students' learning experiences. Once developed, these educational games will be assessed for their effectiveness in enhancing students' mathematical understanding, particularly in the topic of numbers. By integrating technology into mathematics education, this research seeks to bridge the gap between traditional learning methods and the digital era, ultimately fostering a more engaging and effective educational environment.

B. METHODS

This research employs a qualitative methodology supported by quantitative data to develop interactive learning media aimed at enhancing students' mathematical understanding. Conducted from October 17 to November 13, 2024, the study involves 26 seventh-grade students from MTS in Banyuasin Regency and SMP in Palembang City. Both schools used in this study were designated solely as experimental groups. Utilizing the Wordwall platform, this research seeks to create engaging educational games that facilitate learning.

The development process follows Plomp's research model Plomp (2013), which consists of three key stages: Preliminary, Development (Prototyping), and Assessment. The Preliminary Stage involves selecting research subjects and locations, analyzing learning materials, reviewing the curriculum and textbooks, communicating with teachers, and preparing essential resources. In the Development (Prototyping) Stage, the educational game undergoes design, implementation, and validation to ensure its quality and effectiveness. The selection criteria for validators in an Android-based game designed to enhance students' mathematical literacy include expertise in mathematics education, experience in educational game development, and

familiarity with digital learning tools. Validators should also have a strong understanding of curriculum standards and pedagogical approaches to ensure the game's validity and effectiveness. Finally, the Assessment Stage evaluates the effectiveness of the Android-based game "Wall of Word" through assessment tests conducted after field trials. By following this structured approach, the research aims to produce a well-designed, effective, and engaging educational game that enhances students' ability to master mathematical concepts.

Data collection in this study was conducted through Android game validation sheets, questionnaires, interviews, and student mathematical literacy tests, which included pre-tests and post-tests on number concepts. The validation sheet consists of four aspects: content, construct, ICT, and language, which are further divided into 20 questions. The questionnaire consists of 10 statements and is used to assess the practicality of the game. The pre-test and post-test consisted of 15 questions covering topics such as integers, rational numbers, and arithmetic, categorized into easy, medium, and difficult levels.

Student learning outcomes serve as an indicator of the effectiveness of media usage in learning. The quantitative data in this study were derived from skill assessments on the educational game media, while the qualitative data were obtained from student questionnaires as media users. Quantitative data were analyzed using percentages and N-gain values, while qualitative data were examined through descriptive analysis to ensure alignment with the quantitative approach. To ensure validity, mathematics teachers and lecturers acted as validators, conducting validation activities for the Android-based game. Validation tools were used to assess both content and media feasibility, applying a Likert scale from 1 to 5. The percentage of validity and practicality indices for all aspects was then calculated using this formula.

$$P = \frac{S}{N} \times 100\% \tag{1}$$

Description: P is percentage of sub variables; S is total score of each sub; and N is total maximum score. Furthermore, the results of the recapitulation according to the categories in Table 1 below.

Table 1. Validity and Practicality Criteria

No	Interval	Description
1	84% < Score ≤ 100%	Very Good
2	68% < Score ≤ 84%	Good
3	52% < Score ≤ 68%	Fair
4	36% < Score ≤ 52%	Less
5	20% < Score ≤ 36%	Very Poor

To evaluate the performance of the Android-based game, this study utilized pre-tests, post-tests, and student response questionnaires. After administering these tests, an analysis was conducted to assess students' cognitive levels. The pre-test and post-test results were measured using normalized gain (N-gain) to determine the improvement in students' understanding. In addition to quantitative data, qualitative data were obtained from validator assessments, which involved evaluating the Android game based on standardized validation

criteria. The effectiveness test results were analyzed using the N-gain method, as proposed by Hake (Nissen et al., 2018).

$$g = \frac{(\text{Posttest score} - \text{pretest score})}{(maximum\ score - minimum\ score)} \quad (2)$$

This approach aimed to measure both students' achievement and the improvement in their learning outcomes before and after using the Android-based game. Table 2 presents the N-gain category guidelines and the formula used in this study.

Table 2. N-gain category guidelines

No	Score N-gain	Category
1	$g \geq 0{,}7$	High
2	$0{,}3 \leq g < 0{,}7$	Moderate
3	$g < 0{,}3$	Low

C. RESULT AND DISCUSSION

This research focuses on the development of Android-based educational games aimed at enhancing students' mathematical literacy, particularly in number-related topics such as integers. The goal is to create a valid, practical, and engaging learning tool that can effectively support students in understanding mathematical concepts. Following the Plomp development model, the final product is expected to be an Android-based game that is not only interactive and user-friendly but also has the potential to significantly improve students' mathematical literacy skills.

1. Preliminary stage

This research began with the analysis and preparation stage, which involved identifying the curriculum, analyzing learning materials, and assessing students' needs in seventh-grade classrooms at MTS GUPPI Sukamoro and SMP Srijaya Negara. Based on the data obtained, the curriculum used in this study is the Independent Curriculum. Observations revealed that number topics, particularly integers and rational numbers, were among the most challenging for students, as difficulties were still encountered in delivering and understanding the material. Additionally, an analysis of student needs indicated that the use of technology-based learning media, such as Android-based games, remains limited, despite the availability of adequate technology and a supportive learning environment. This finding highlights the need for innovative learning tools to enhance students' engagement and comprehension of mathematical concepts.

2. Prototyping Stage

Following the preliminary stage, the next step in this research is the design and development of an Android-based game tailored to students' needs, curriculum requirements, and learning materials. The Wordwall platform was selected as the foundation for the game, as it provides interactive and engaging learning experiences to support students' mathematical literacy. The game was designed with an interesting and visually appealing theme, ensuring that students remain motivated while completing each task to enhance engagement. The game

structure incorporates multiple levels, each with varying degrees of difficulty, guiding students progressively toward mathematical literacy. This level-based approach is intended to stimulate curiosity, encourage active participation, foster creativity, and enhance students' responsiveness in problem-solving. The following section presents the design outcomes of the Android-based educational game developed using Wordwall, as shown in Figure 1 and Figure 2.

Figure 1. Game initial view

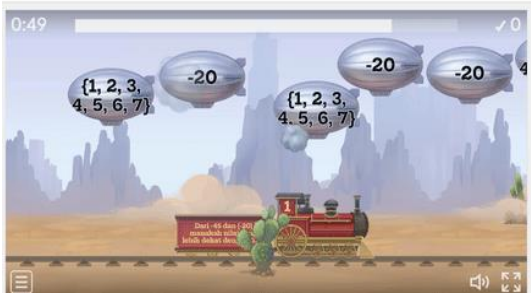

Figure 2. Level 1 display

In Figure 1, the initial game screen provides students with instructions and an explanation of the game's objectives. After clicking the "Start" button, Figure 2 appears, displaying the first level of the game. At this stage, students are presented with a basic math challenge featuring a single car and low-level questions. To achieve the highest score, students must answer correctly while racing against time, with each game session limited to one minute. Upon completing the first level, students will advance to the next level, where they will encounter progressively more challenging questions, as shown in Figure 3 and Figure 4

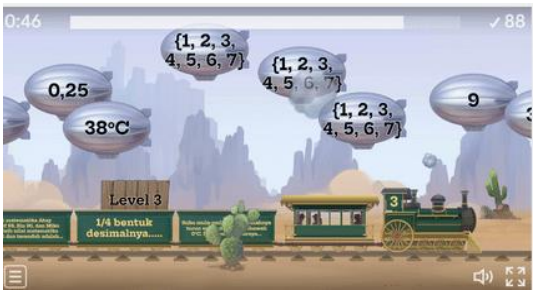

Figure 3. Level 2 game display

Figure 4. Final display

In Figure 3, the game becomes more challenging as the number of cars increases to two, while the duration remains one minute. At this stage, students can still answer questions at a relaxed pace, gradually adapting to the game's mechanics. Upon completing the second level, they advance to Level 3, where the challenge intensifies with the introduction of three train cars within the same one-minute timeframe. At this point, students are encouraged to focus more, as the game becomes increasingly engaging with moderate-level questions, further enhancing their problem-solving skills.

In Figure 4, as the game approaches its final levels, additional time and extra coins are introduced, enhancing the excitement and engagement of the gameplay. At the end of the game, students will see their final scores, leaderboards, and a summary of their answers. Additionally, after completing the first game, students will receive a second link to proceed to the next game,

which features medium and high-level challenges, further testing their mathematical skills and problem-solving abilities.

Figure 5. Initial view of the game 2

Figure 6. Game 2 level 2 display

Figure 5 shows the second game. In the second game, students are first provided with instructions, and upon clicking "Start," the game begins at Level 1, featuring medium-level questions that require two correct answers. Unlike the previous game, where the score was based on collecting the highest number of coins, this version introduces a new challenge—students must answer questions correctly while managing a limited number of lives, adding an extra layer of strategy and engagement to the learning experience.

In Figure 6, the game progresses to Level 2, where students must identify three correct answers based on the given statements in the questions. At Level 3 of the second game, the challenge increases as students are required to find four correct answers, encouraging them to think quickly and carefully. Accuracy becomes crucial, as rushing through the questions without proper focus may lead to mistakes. Without realizing it, this second game effectively enhances students' mathematical literacy, helping them develop both problem-solving skills and critical thinking abilities.

Figure 7. Game 2 level 4 display

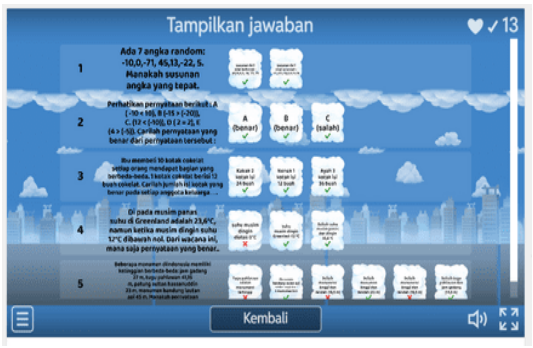

Figure 8. End-game view

In Figures 7, the game progresses to higher difficulty levels, where Level 4 requires identifying two correct statements, while Level 5 increases the challenge to three correct statements. Meanwhile, Figure 8 displays the game's final screen, which is similar to Game 1 but with differences in the answer display format and scoring system. After the product design and prototyping process, the game was refined in stages according to the development phase. The process then moved to Prototype 2, which involved two key steps: (1) expert validation and (2) limited-scale game trials. The selection criteria for validators in an Android-based game

designed to enhance students' mathematical literacy include several key aspects. First validators must have expertise in mathematics education to ensure that the game's content aligns with mathematical concepts and learning objectives and should have a strong understanding of curriculum standards to ensure that the game meets educational requirements. Lastly, knowledge of pedagogical approaches is crucial for assessing whether the game supports meaningful learning experiences and effectively enhances students' mathematical literacy.

Second validator should have experience in educational game development, enabling them to assess the game's instructional design, engagement level, and effectiveness as a learning tool, and familiarity with digital learning tools is essential, as it allows validators to evaluate the technological aspects, usability, and accessibility of the game. In the first validation stage, the Android-based game was evaluated by material experts, who rated it at 78.48%, and by media experts, who gave it 83.45%. During this validation, several suggestions and criticisms were provided, including adjusting grammar to avoid confusing sentences, extending the time limit in Game 1, and increasing the number of lives in Game 2 to improve gameplay balance. Additionally, literacy-based questions were enhanced with relevant images to make them more engaging.

The limited-scale trial was conducted twice before the field test using one-to-one and small-group testing methods. In the one-to-one trial, three students with different ability levels participated. Based on their feedback, additional lives were incorporated, and the font style was adjusted for better readability. In the small-group trial, six students were divided into two groups, and after completing the game, they filled out a questionnaire consisting of 11 questions to assess the practicality of the Android-based game. The results showed a practicality score of 77.54%, classifying the game as good and practical. With these refinements, Prototype 3 was finalized and prepared for field testing.

3. Assessment

After completing the prototyping stage, the research proceeded to the assessment stage, which serves as a summative evaluation to determine the effectiveness, efficiency, and attractiveness of the developed product. This assessment involved field trials through data collection and testing. The field tests were conducted at MTs GUPPI Sukamoro over three sessions on October 19, October 22, and October 26, 2024, and at Srijaya Negara Junior High School on November 4, November 7, and November 11, 2024. Although conducted at different times, both schools followed the same format, with each session lasting two lesson hours.

The assessment process began with a pretest to evaluate students' initial knowledge before using the Android-based game in their learning. Students then engaged with the game as the primary teaching tool, designed to enhance their mathematical literacy in number concepts. After completing the learning session, a posttest was administered to measure improvements in their understanding. The results from both the pretest and posttest were analyzed to assess the impact of the Android-based game on students' mathematical literacy, providing insights into its effectiveness in improving number-related competencies.

The final stage of the research is the summative evaluation, which aims to measure student learning outcomes and assess the effectiveness of the Android-based game media. This stage

provides a basis for determining how well the game enhances mathematical literacy and its overall impact on student performance. The effectiveness of the Android-based game is evaluated by comparing pretest and posttest results related to mathematical literacy in number concepts. The following section presents the students' learning outcomes after using the Android-based educational game, as shown in Table 3.

Table 3. Learning outcomes of students at MTs GUPPI Sukamoro and SMP Srijaya Negara

No	Variation	MTs GUPPI Sukamoro		SMP Srijaya Negara	
		Pretest	Post test	Pretest	Post test
1	Highest score	80	98	77	93
2	Lowest score	6	70	13	77
3	Average	49,34	84,69	52,84	83,88
4	Number of students who are complete in learning	5	25	7	26
5	Number of students who are not yet complete in learning	21	1	19	0
6	Classical completeness	19,2%	96,1%	26,9%	100%

Table 3 shows a significant improvement in student learning outcomes after using the Android-based game media. At MTs GUPPI Sukamoro, the average pretest score was 49.34, which increased to 84.69 in the posttest. Similarly, at Srijaya Negara Junior High School, the average pretest score was 52.84, rising to 83.88 in the posttest. This comparison, illustrated in Figure 9, demonstrates that the Android-based game effectively enhances students' mathematical literacy, particularly in number concepts.

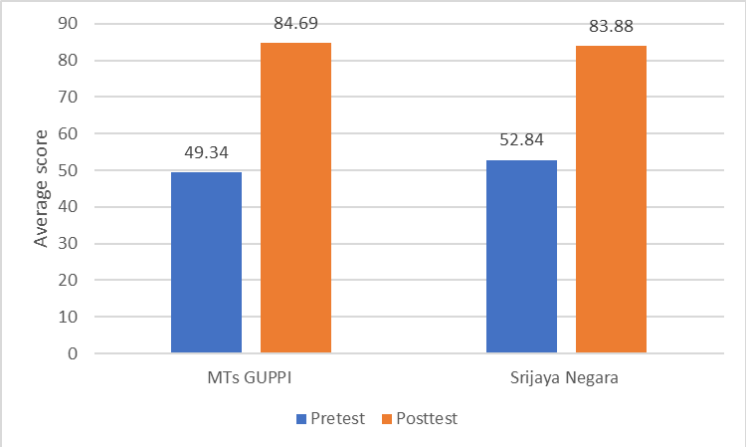

Figure 9. Result Test

Additionally, there was a notable increase in classical completeness. At MTs GUPPI Sukamoro, it rose from 19.2% in the pretest to 96.1% in the posttest, while at Srijaya Negara Junior High School, it improved from 26.9% in the pretest to 100% in the posttest. Further details on the average student scores can be found in Tables 4 and Table 5 below.

Table 4. Average Increase in MTs GUPPI Student Scores

Test	Total score	Average	N-gain	Category
Pretest	1283	49,34	0,648	Moderate
Posttest	2202	84,69		

Table 5. Average Increase in Grades of Srijaya Negara Junior High School Students

Test	Total score	Average	N-gain	Category
Pretest	1374	52,84	0,576	Moderate
Posttest	2181	83,88		

Based on the data from Tables 3 and Table 5, the effectiveness test results for seventh-grade students at MTs GUPPI Sukamoro showed an N-gain score of 0.65, which falls into the moderate category. Similarly, as seen in Table 3 and Table 6, the N-gain score for seventh-grade students at Srijaya Negara Junior High School was 0.58, also categorized as moderate. These results indicate that the implementation of Android-based games in both schools led to a notable improvement in students' mathematical literacy, particularly in seventh-grade classes, where the increase remained within the moderate category. Examples of student responses demonstrating a strong understanding of mathematical literacy from both schools can be seen in the Figure 10 and Figure 11.

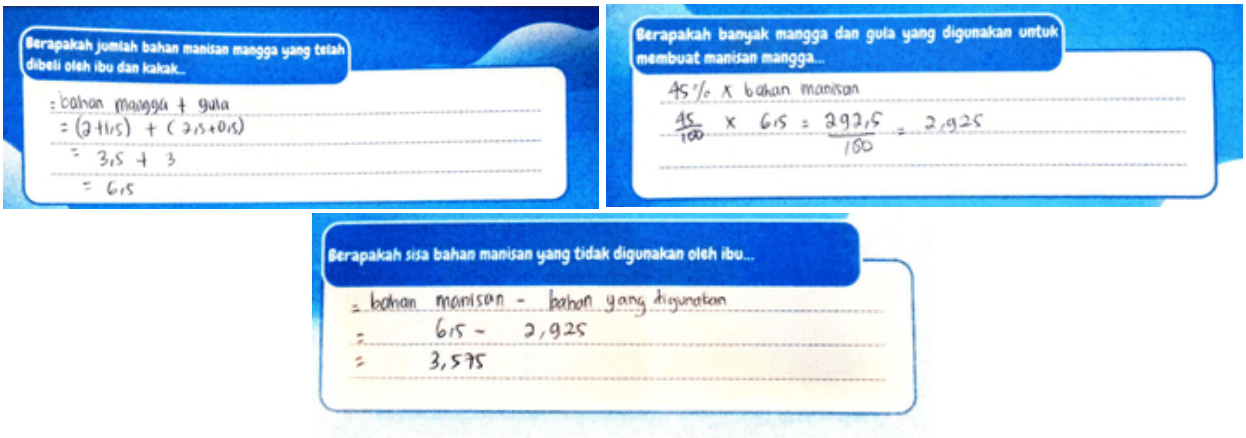

Figure 10. Sample student answers at MTs GUPPI

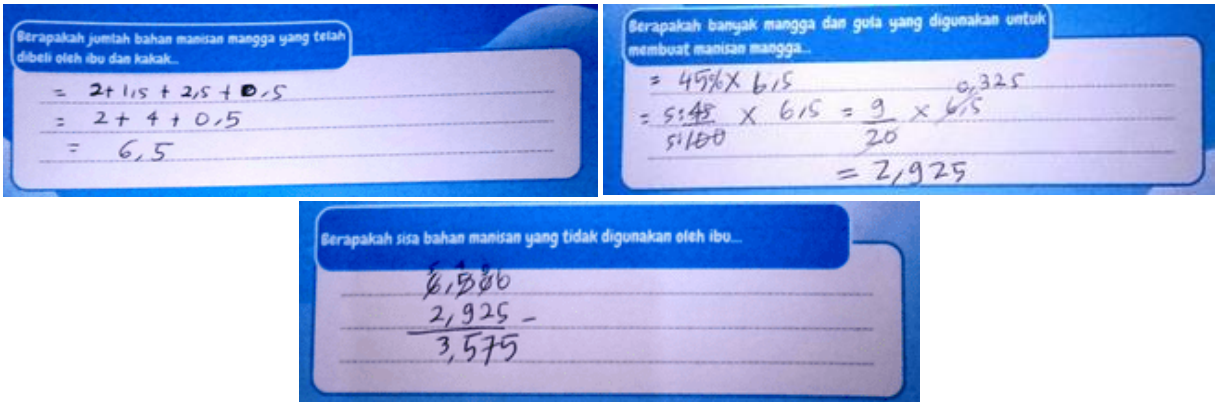

Figure 11. Sample student answers at Srijaya Junior High School

Mathematical literacy refers to the ability to apply mathematical thinking in solving everyday problems, equipping individuals with the necessary skills to face real-life challenges. This includes problem-solving, logical reasoning, communication, and explanation, all of which are developed through an understanding of mathematical concepts, procedures, and relevant facts (Stecey & Turner, 2015). Similarly, Genc & Erbas (2020) highlights that while students tend to rely on procedural and concrete approaches to problem-solving, they have demonstrated the ability to analyze and extract information from mathematical problems. In this regard, Android-based game media plays a crucial role in enhancing mathematical literacy, particularly in number-related topics, as supported by Arigunawan et al. (2020), who found that game-based media significantly aids in understanding integer concepts in mathematical literacy. The responses from students in both schools demonstrate strong mathematical literacy skills, as they were able to comprehend, interpret, and correctly solve problems, despite using different approaches to reach the correct solution.

D. CONCLUSION AND SUGGESTIONS

Based on the results of this study, it can be concluded that: (1) Android-based games are proven to be feasible and effective in enhancing mathematical literacy in number concepts, as they meet theoretical criteria in terms of content, media, language, and presentation; (2) Android-based games are valid and suitable for use in learning, receiving positive responses from both teachers and students as they align well with school conditions in both urban and rural areas; and (3) the improvement in students' mathematical literacy through the use of Android-based game media is highly significant, as reflected in the pretest and posttest scores. At MTs GUPPI Sukamoro, the average pretest score was 49.34, increasing to 84.69 in the posttest. Similarly, at Srijaya Negara Junior High School, the average pretest score was 52.84, rising to 83.88 in the posttest. These findings confirm that Android-based games are effective in improving students' mathematical literacy, particularly in integers and rational numbers, while also contributing to overall learning achievement. The effectiveness test results showed an N-gain score of 0.65 for students at MTs GUPPI Sukamoro, which falls into the moderate category. Similarly, students at Srijaya Negara Junior High School achieved an N-gain score of 0.58, also classified as moderate.

For future research, it is recommended to focus on developing additional game features, expanding the scope of mathematical content, and implementing strategies to enhance player interaction. Improving game features, such as adaptive difficulty levels, interactive tutorials, and real-time feedback, can further support student engagement and learning. Expanding the content coverage to include a wider range of mathematical concepts can make the game more comprehensive and applicable to different learning levels. Additionally, incorporating strategies to increase interaction, such as multiplayer modes, collaborative problem-solving, or gamification elements like leaderboards and rewards, can enhance student motivation and engagement with the learning process.

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