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Developing a Mathematical Literacy Learning Environment for Students through Educational Game Assistance

Ida Hamidah[1], Zulkardi[1, *], Ratu Ilma Indra Putri[1], Surya Amami Pramuditya[2]

[1]Mathematics Education Study Program, Sriwijaya University, Palembang, Indonesia
[2]Mathematics Education Study Program, Swadaya Gunung Jati University, Cirebon, Indonesia
[*]Email: zulkardi@unsri.ac.id

Abstract

Mathematical literacy is a fundamental skill that enables students to solve real-life problems, think critically, and make informed decisions across various contexts. Its absence can impede students' academic success and limit their ability to address challenges in a technology-driven world, underscoring the importance of this research in enhancing their future opportunities. A significant factor contributing to this issue is the inadequate implementation of teaching practices that support mathematical literacy in schools. To address this challenge, this study aims to develop a valid, practical, and impactful mathematical literacy learning environment for junior high school students using educational game assistance. A design research method with a developmental research approach was employed, consisting of three stages: the preliminary stage, prototype development, and evaluation. The data were analyzed through qualitative descriptive analysis. This study developed a mathematical literacy learning environment leveraging educational game technology to enhance student learning. The environment was validated in terms of content, construct, and language aspects, deemed practical for its ease of use, accessibility, flexibility, and alignment with learning objectives, and evaluated for its potential impact based on Guskey's five-levels framework. The results highlight its potential impact on improving mathematical literacy and addressing the challenges posed by inadequate teaching practices in schools. This research underscores the importance of integrating innovative educational tools to better prepare students for success in a technology-driven world.

Keywords: Educational Games, Framework, Learning Environment, Mathematical Literacy, PISA

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INTRODUCTION

Mathematical literacy is an essential skill for students to address complex challenges of the 21st century (Sitopu et al., 2024). It enables students to reason mathematically, as well as to formulate, apply, and interpret mathematics in solving real-world problems (OECD, 2023c). This skill equips individuals to address life challenges effectively and make informed decisions that impact their personal lives, work, and society, fostering systematic, conceptual, and causal thinking (Utami et al, 2023; Fauziah & Pandra, 2023). Therefore, mathematical literacy is a critical competency for students to prepare future challenges. The 2022 Programme for International Student Assessment (PISA) results reveal low and concerning mathematical literacy performance in Indonesia, with scores consistently below the international average across consecutive assessments (OECD, 2023c). Recent studies further highlight persistent deficiency in students' mathematical literacy skills (Putri & Zulkardi, 2020; Nurjanah et al., 2023; Susanta et al., 2023). A key contributing factor is the limited implementation of the teaching process that supports mathematical literacy in schools (Bolstad, 2023; Maslihah et al., 2021). Therefore, effective solutions are urgently required to address these challenges and enhance students' mathematical literacy skills.

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Research underscores the significant role of teaching practices in enhancing students' mathematical literacy skills. Strategies such as incorporating various representations and fostering meaningful mathematical discourse enhance conceptual understanding and student engagement. By encouraging students to explore and discuss problem-solving approaches, teachers create a classroom environment where mathematical ideas are internalized through peer interactions and active participation (Bohlmann & Benölken, 2020). Additionally, effective teaching practices prioritize structured problem-solving and diverse strategies, promoting a productive struggle that enriches students' learning experiences (Jackson et al., 2021).

Teaching practices that connect mathematical learning to real-world contexts and encourage reflection significantly enhance students' ability to apply mathematical concepts across diverse situations (Utami et al, 2023; Fauziah & Pandra, 2023). These approaches align with international educational standards, highlighting their role in addressing global challenges in mathematical literacy. These findings highlight the importance of adopting innovative and interactive teaching strategies to strengthen students' mathematical literacy, preparing them for complex problem-solving in future academic and real-world scenarios.

Mathematical literacy skills can be enhanced through a teacher's role and competence in teaching mathematical literacy to students (Nortvedt & Wiese, 2020; Bolstad, 2020). Teachers play a crucial role in shaping positive perceptions of mathematics, designing self-efficacy learning, selecting appropriate teaching methods, and motivating students to understand mathematics as a foundational pillar for the development of science and technology (Utami et al, 2023; Fauziah & Pandra, 2023). A real example of the role of teachers in improving students' mathematical literacy is Singapore's achievement as a top performer in PISA 2022 assessment (OECD, 2023a). Teachers in Singapore implement differentiated teaching, a learner-centered approach that adapts to changes in technology, socio-cultural, politics, and modernization (Heng & Song, 2023). Therefore, teachers' role in developing appropriate learning tools and environments to support mathematical literacy skills is crucial.

The role of teachers in implementing diverse teaching methods, media, and materials is part of the learning environment. Phillips et al. (2010) define the learning environment as the space where students engage in learning, encompassing physical and virtual spaces, programs, content, and resources that support student learning. This environment also includes the use of technology, teacher-designed learning activities, and assessments that facilitate students' learning. In simple terms, Zulkardi (2002) defines the learning environment as the place where learning takes place. Efriani et al. (2023) distinguishes learning environments into two categories: minimalist and rich learning environments. Minimalist learning environments include sources of information, assignments, and feedback. In contrast, rich learning environments provide more resources for manipulating phenomena and offer students greater control over the learning process. The OECD (2023b) explains that an effective learning environment supports pedagogy, curriculum, assessment, and teaching methods necessary to develop students' 21st century skills. Thus, a well-structured learning environment is essential for improving students' mathematical literacy skills.

Previous studies on mathematical literacy skills have primarily focused on learning models and the development of learning tools, such as PISA-like question activities in printed media, such as modules and student worksheet (Zulkardi & Kohar, 2018; Zulkardi & Putri, 2020; Nusantara et al., 2020). While these studies have made practical solutions to enhance students' mathematical literacy skills in schools, they mainly emphasize familiarizing students with solving PISA-like questions and equipping teachers to design similar questions effectively. However, there remains a gap in research, particularly regarding the use of more interactive, technology-driven media that centers students-involvement, beyond mere learning videos.

Research by Rachmadtullah et al. (2018) highlights that interactive media enhances students' motivation and engagement by incorporating multimedia elements such as animations and gamification, which make abstract concepts more accessible. Similarly, Puspitarini & Hanif (2019) emphasize that the immediate feedback provided by interactive platforms enhance students' understanding, a benefit that static learning materials fail to provide. Educational games, as a subset of interactive media, enhance the learning experience by integrating mathematical tasks with game mechanics. Ojose (2011) explains that educational games establish meaningful connections between mathematics and real-world applications, improving retention and problem-solving abilities. Rahayu & Kuswanto (2021) argue that the gamified nature of these tools motivates learners, fosters creativity, and enhances critical thinking, addressing key components of mathematical literacy.

Educational games, combine learning objectives with gaming mechanics to create a motivating and effective learning environment. Research has demonstrated that digital educational games are highly effective in enhancing mathematics learning by presenting complex concepts in an accessible and engaging manner. For example Tepho & Srisawasdi (2023) found that integrating tablet-based educational games into mathematics instruction increased student engagement and improved their mathematics performance over the course of a semester. Games actively engage cognitive processes such as recall, pattern recognition, and decision-making, making them ideal for developing mathematical literacy (Rahayu & Kuswanto, 2021).

One popular and user-friendly type of educational game is the Role-Playing Game (RPG). As the name implies, RPG involves players assuming roles defined by the game narrative, with the goal of achieving specific objectives (Winardy & Septiana, 2023; Wibawanto, 2020). RPG are a form of interactive learning media that positively impact student engagement, making learning more exciting and less monotonous (Alt, 2023; Winardy & Septiana, 2023). Additionally, learning through RPG enhances cognitive abilities and helps reduce students' stress and boredom in learning mathematics (Dai et al., 2023; Azzumar & Rosjanuardi, 2024; Saputra et al., 2024). While several studies have successfully developed games with positive impacts, such as an Android version to support online learning (Satria & Herumurti, 2021) and a windows version to enhance critical thinking skills (Azzumar & Rosjanuardi, 2024), no research has yet focused on developing an RPG to improve mathematical literacy skills.

Therefore, to address the gap in research on interactive media for enhancing mathematical literacy skills and the absence of research on RPG learning media for this purpose, this study aims to develop a learning environment through RPG games to support mathematical literacy. In this learning environment, students will be the central focus, with RPG integrated into the learning process through a series of activities and missions that students must complete.

METHODS

This study employs qualitative research design using a developmental study approach, following three stages: introduction, prototyping, and assessment (Plomp & Nieveen, 2010). This methodology effectively addresses the research questions, aligning with the study's objectives. By focusing on development of a learning environment that integrates technology, educators can create dynamic spaces that increase student engagement, promote interactive learning, and prepare students for the demands of the digital future.

In this study, the preliminary stage focuses on analysis and design. The prototyping stage follows the formative evaluation process (Ahyan et al., 2014; Tessmer, 2019) as illustrated in Figure 1. The assessment is based on five levels of Guskeys development: participants' reaction, participants' learning, organizational support and change, participants' use of new knowledge and skills, and student's learning outcomes (Guskey, 2016).

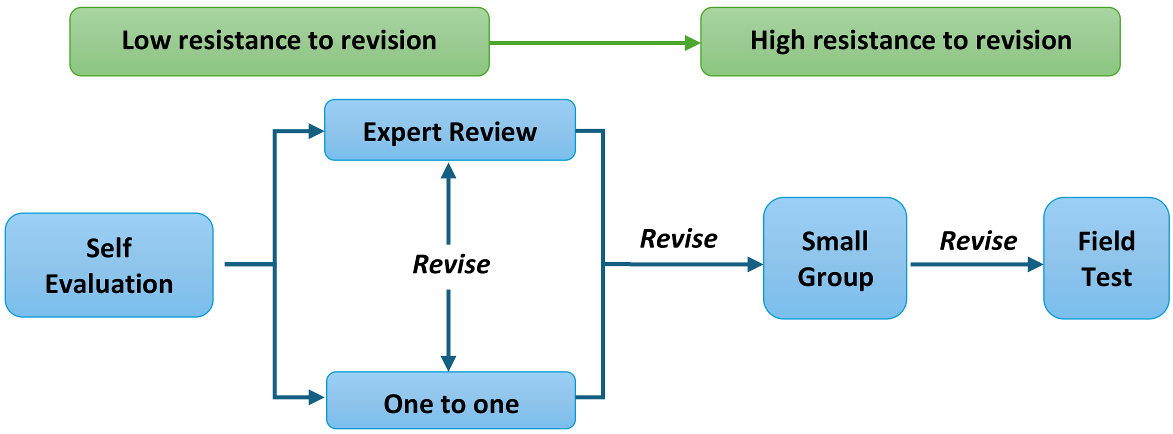


Figure 1. Formative evaluation flow

In the preliminary stage, the researcher conducted a literature review on mathematical literacy, learning environment, Indonesian Realistic Mathematics Education (PMRI) (which is an adaptation of the Dutch Realistic Mathematics Education (RME) framework) mathematical content, educational role-playing games (RPG), real-world contexts relevant to students, an initial draft of the learning environment, and the selection of the study location and participants, specifically junior high school students in the Cirebon area.

The prototyping process involved formative evaluation across several phases. First, during the self-evaluation phase, the researcher independently assessed the designed learning environment. Next, in the expert review/focus group discussion (FGD) phase, the researcher presented the prototype for validation by experts, with the discussion focusing on content, constructs, and language. The experts included three lecturers from various universities, two practicing teachers familiar with RPGs, and one doctoral student in mathematics education with an interest in mathematical literacy learning environments. Simultaneously with the FGD phase, a one-on-one phase was conducted with six students with various abilities. Feedback and suggestions gathered during these sessions served as the basis for improvement, resulting in the revised prototype, referred to as prototype 2.

In the small group phase, Prototype 2 underwent further testing with 12 students of varying abilities. Observations focused on student responses to assess practicality, including ease of use, accessibility, flexibility, and alignment with learning objectives. Finally, the field test phase was conducted using prototype 3, a revision of prototype 2. During this phase, Prototype 3 was tested in a class of 30 students to evaluate the overall practicality of the developed instrument.

At this stage, the potential impact of the developed learning environment is assessed based on Guskey's five levels of development. The first level, participant reactions, evaluates student satisfaction after the prototype trial. The second level, participant learning, focuses on student perceptions after experiencing the prototype. The third level, organizational support and change, examines the level of school support and any changes resulting from the prototype trial. The fourth level, participant use of new knowledge and skills, assesses how students applied what they learned after the trial. Finally, the fifth level, student learning outcomes, measures the impact on students' mathematical literacy skills after implementation.

Data collection techniques for this study employed multiple methods to ensure thorough evaluation and feedback at various developmental stages. Walk-throughs were conducted during the expert review or focus group discussion (FGD) phase to validate the developed prototype and related assessment instruments while collecting expert feedback and suggestions for refining Prototype 1. Questionnaires were distributed to students after the learning session to assess their satisfaction and perceptions of the prototype. Tests were administered during the field test stage to evaluate potential impacts on students' mathematical literacy skills. Observations were conducted throughout all stages to monitor classroom implementation and evaluate validity, practicality, and potential effects. Finally, interviews were conducted during the one-to-one, small group, and field test stages to gather additional data beyond the scope of questionnaire or observations, offering deeper insights and enriching the overall assessment. The data were analyzed descriptively, encompassing walkthrough data, questionnaires, tests, and observations. Suggestions and comments from experts, as well as findings from observer results and interviews, were analyzed qualitatively using a descriptive method.

RESULTS AND DISCUSSION

This section explains the development process of a valid, practical, and potentially impactful mathematical literacy learning environment for junior high school students, utilizing interactive RPG-based learning media aligned with the PISA framework. This learning environment integrates game application technology, allowing students to take on the role of central characters within a purposeful game narrative. Below is an explanation of the development process and the findings at each stage.

Preliminary

In the preliminary stage, the researchers developed a test instrument based on the PISA framework, tailored to the characteristics of the students, along with a game scenario serving as the narrative for the RPG. They also created initial coding for the RPG game, incorporating both the test instruments and game scenario as part of the draft for the RPG-assisted learning environment. The content focused on algebra material for grade VII junior high school students, aligned with the independent curriculum. This material was selected to introduce mathematical literacy at an early stage, ensuring that by the time students reach the age of 15 and participate in the PISA assessment, they are familiar with and proficient in mathematical literacy skills in PISA questions.

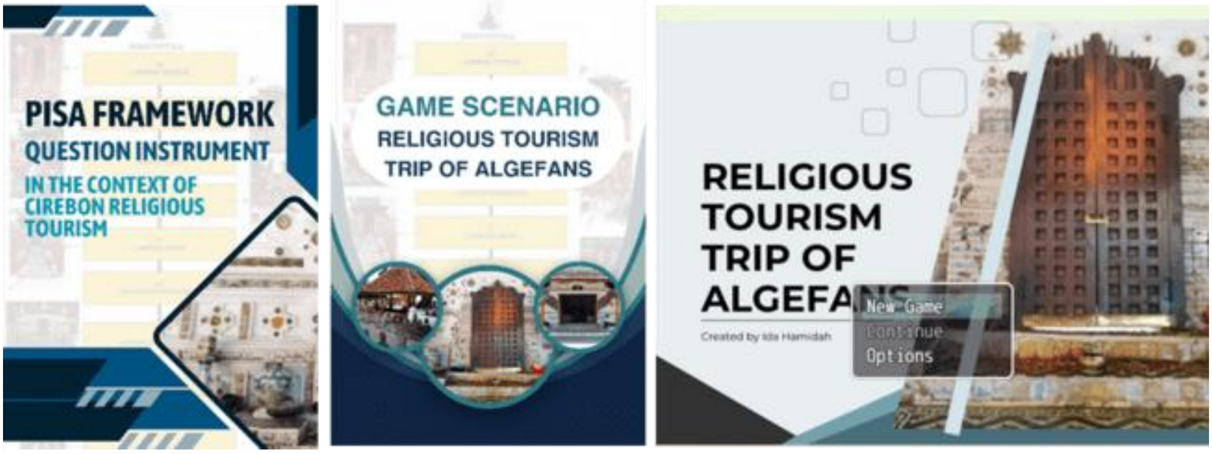


Figure 2. Results of the Preliminary Stage

Figure 2 illustrates the result of the preliminary stage. At this stage, a set of test instruments, a draft of the game scenario, and an initial display of the game design were developed. The PISA framework-based test instrument encompasses learning outcomes and objectives aligned with the algebra material for grade VII in the independent curriculum, modified to meet the research needs and subjects' characteristics. The competencies incorporated are based on the PISA 2022 framework, emphasizing mathematical reasoning and problem-solving within the content areas of quantity, relationships and changes, and space and shape. These competencies are applied in personal, scientific, work, and community contexts. Additionally, the activities designed within the instrument align with the levels of activities outlined in the PISA framework.

The game scenario is created around a storyline connected to algebra, with missions embedded in the story containing questions from the instruments obtained. The scenario includes five key elements: welcome map, activity map, challenge map, punishment, and reward. In the welcome map, students are introduced to the adventure through a prologue that outlines the journey and its objectives. The activity map contains interactive dialogues where students play the role of characters and indirectly learn algebra. The challenge map serves as an evaluation phase, testing students on the concepts explored in the preceding activity. The punishment involves a 'game over' scenario, requiring students to restart the adventure. The reward includes progression to higher level and victory in the game.

Figure 3. Initial Narration of the Game, Story Introduction

Figure 3 shows the initial display upon starting the game, representing an iconic view of the Sunan Gunung Jati tomb complex in Cirebon. Sunan Gunung Jati is a prominent figure in the spread of Islam in Java. In this stage, students are introduced to the game objectives and the story elements embedded in the activities. The map highlights the Sunan Gunung Jati tomb, a key tourism icon in Cirebon that attracts visitors across the country and internationally, including China. This site holds historical significance as it also contains the grave of a Chinese princess who was the wife of Sunan Gunung Jati.

Figure 4. Explanation of the main characters and missions that must be completed

Figure 4 illustrates a map displaying the description of the main character in this game and an explanation of the mission of the activities students will undertake in their role as the main character. The map explains that to reach the main tomb of Sunan Gunung Jati, nine doors must be passed. However, access for the general public extends only to the third door. Therefore, the main character is tasked with completing a series of missions to reach the final destination, the main tomb of Sunan Gunung Jati.

The narrative in this game is based on the real conditions of the Sunan Gunung Jati's tomb, allowing students to not only learn but also experience a virtual travel journey. Beyond being a religious attraction, the tomb of Sunan Gunung Jati holds significant cultural elements and conveys many positive values for students to reflect upon. Located in Cirebon, the tomb serves as both an important religious site and a focal point of cultural and spiritual traditions. The site is part of the broader legacy of the Wali Sanga, representing a deeply rooted tradition in which pilgrimage plays a vital role in connecting individuals with their spirituality and the divine. Visitors come to the tomb to seek blessings or *ngalap berkah*, which is believed to bring fulfillment in various aspects of life, including health, prosperity, and personal desires (Musrifah, 2018; Agustina et al., 2024).

The tomb complex also represents the enduring connection between past and present, highlighting a shared identity grounded in cultural and spiritual practices. The tradition of visiting the site reinforces values such as gratitude, respect for ancestors, and faith, which are essential components of community values in Cirebon.

Figure 5. Main Character Interaction in Completing the Mission

Figure 5 shows the next map, where the main character begins to move under student control. In this map, the environment is much larger than in the first and second maps. Students have full control over the main character's movement, but guidance is provided to help students navigate and complete their missions. The guidance comes through interactions between main characters and the Non-Playable Character (NPC), where students can engage in conversations to receive directions for progressing in the game. On this map, students will learn algebra, understand examples of algebra, and practice related questions. The questions are designed to align with the characteristics of the PISA framework. When students answer a question correctly, they unlock access to the next map. However, if they answer incorrectly, the game ends, and they must restart from the beginning. The game concludes when students successfully reach the top of the Sunan Gunung Jati tomb complex in Cirebon.

To conduct a deeper needs analysis, the researchers held discussions with the mathematics teachers at the school to review whether the test instruments, story scenarios, and game drafts were aligned with the characteristics and developmental needs of the students. The feedback and responses gathered from the teachers during these discussions were utilized by the researchers to enhance the development of the instruments and the design of the learning environment. Through in-depth problem analysis, an extensive literature review, instrument development, game scenario design, and discussions with school teachers, the researchers successfully conceptualized a framework for a mathematical literacy learning environment supported by an RPG game, as illustrated in Figure 6.

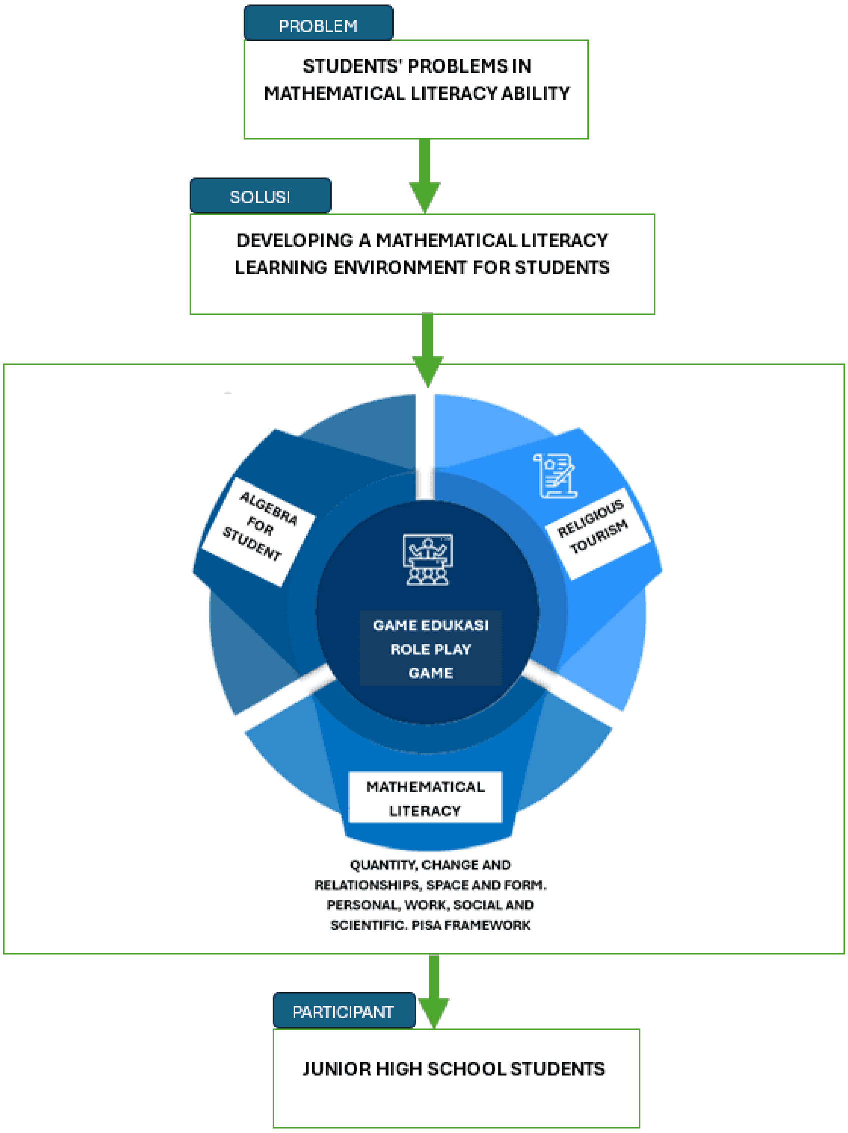


Figure 6. Conceptual Framework of RPG Mathematical Literacy Learning Environment

Figure 6 presents the concept of the learning environment developed in this study. The RPG learning environment, aligned with the PISA framework, was successfully created with game instruments and scenarios as its content. The development process involved collaboration with mathematics teachers at the school where the research subjects were located. In addition, the mathematics teacher acted as an observer during the small group learning phase, and later implemented the findings and observations obtained at the field trial stage. All materials and outcomes from this preliminary stage were then carried forward to the prototyping stage, which represents the formative evaluation stage.

Prototyping

The prototype creation stage in this research followed a formative evaluation flow. The first stage of this evaluation is self-evaluation, where the researcher examines and evaluates the developed activities. The aspects evaluated include content, construction, and language. In addition, media-related aspects are also assessed at this stage. If any issues such as typos, word choices, or inconsistencies in the media design are identified, improvements are made accordingly. This stage produces student activities in RPG media, set in the context of religious tourism of the Sunan Gunung Jati tomb in Cirebon, focusing on algebra material for grade VII. The activities are designed to align with the mathematical literacy competencies in the PISA framework, with the questions structured according to PISA characteristics. Furthermore, prototype 1 was validated at the FGD and one-to-one stages, which were conducted simultaneously. At the FGD and one-to-one stages were carried out in parallel. This stage aims to determine the validity of prototype 1, developed in the previous stage, based on predetermined criteria, also known as Walkthrough. During this phase, the validators provided feedback and suggestions regarding content, construction, and language.

The valid characteristics of the game can be categorized into three aspects: content, construct, and language. Regarding content, the game aligns with the Kurikulum Merdeka (Independent Curriculum), adheres to algebraic concepts and definitions, and meets the criteria for mathematical literacy problems. The material is tailored to the cognitive level of Grade VII junior high school students and effectively incorporates the context of the Sunan Gunung Jati tomb complex. From a construct perspective, the content and examples are clearly presented in the media, with algebra material organized in a logical sequence. The game design and color scheme are balanced, avoiding excessive elements. In terms of language, the game provides clear instructions through character dialogues, uses language that supports understanding of the storyline, delivers material and instructions effectively, avoiding ambiguity. These characteristics ensure that the game is valid and effective for educational purposes.

In this study, a walkthrough was conducted with six validators who had expertise in RPG, PISA, character values, and language. The validation results, consisting of comments and suggestions, served as material for improving prototype 1. The FGD activities were conducted online via Zoom with experts from various regions in Indonesia, including Jambi, Kerinci, Bandung, Yogyakarta, and Cirebon. All participants in the FGD were practitioners actively involved in writing articles according to their expertise. In parallel, the one-to-one stage took place the day after the FGD stage. The comments and revisions resulting from the FGD and one-on-one activities can be seen in Table 1.

Table 1. Validators Comments and Suggestions

Stage/ Validators	Suggested	Improvements
Preliminary/ FGD: lecturers, teachers, and doctoral students	The mapping is well-organized, spacious, and comprehensive, closely resembling the atmosphere of the Sunan Gunung Jati tomb tour. I appreciate the effort, especially given the limited time, but the results are still impressive. The image is well-positioned, ensuring that text remains unobstructed. Overall, it is effective and can be implemented in the classroom. Suggestions: 1. Implement a game storage feature that allows students to resume their progress after the game ends, preventing the need to start from the beginning and optimizing time efficiency. 2. The final section should conclude with a completed script, directing the player back to the main menu without triggering a game over. 3. Some images have large and small resolutions, it is better to match them, none of them are too small. 4. The questions are lengthy; it is recommended to repeat them to help students recall the information. 5. The learning outcomes are aligned with the content discussed in the research, without including all phases in their entirety. 6. Learning objectives and question indicators are differ; when compiling question indicators, review the sentences and adjust the verbs to align with the corresponding cognitive level. 7. Provide detailed steps or create stages that guide students through the learning process before complete the questions.	1. Implement a game progress saving feature 2. Modify the game-over coding to conclude at the end of the game 3. Standardize the rotation of images displayed in the game 4. Provide supporting modules for students, which not only help them understand literacy questions with lengthy texts but also offer convenience in writing down solution steps when tackling higher PISA-level questions. 5. The learning outcomes focus on phase D of the algebra content, excluding other topics. 6. Enhance the use of language in formulating learning objectives and question indicators. 7. Provide structured guidance to help students learn and understand the material before they tackle the task of solving the questions.

Stage/ Validators	Suggested	Improvements
One to One/ Students	1. Wow, it's great! The picture is adorable, and the story is engaging. However, why does the game restart from the beginning after an incorrect answer, instead of resuming from the last activity before the game over occurred? 2. Ma'am, we've reached the top and the tomb of Sunan Gunung Jati, but why does the game end here? 3. In Unit 2, Question 1 about the shopping center, what does it mean? Also, Unit 4 contains the final question.	The students' comments were largely like those of the experts in the FGD stage, prompting improvements to be made in the same manner as the changes suggested during the FGD. 1. Develop a game progress-saving feature. 2. Replace the game-over map with the completion map. 3. Enhance the language usage in Units 2 and 4.

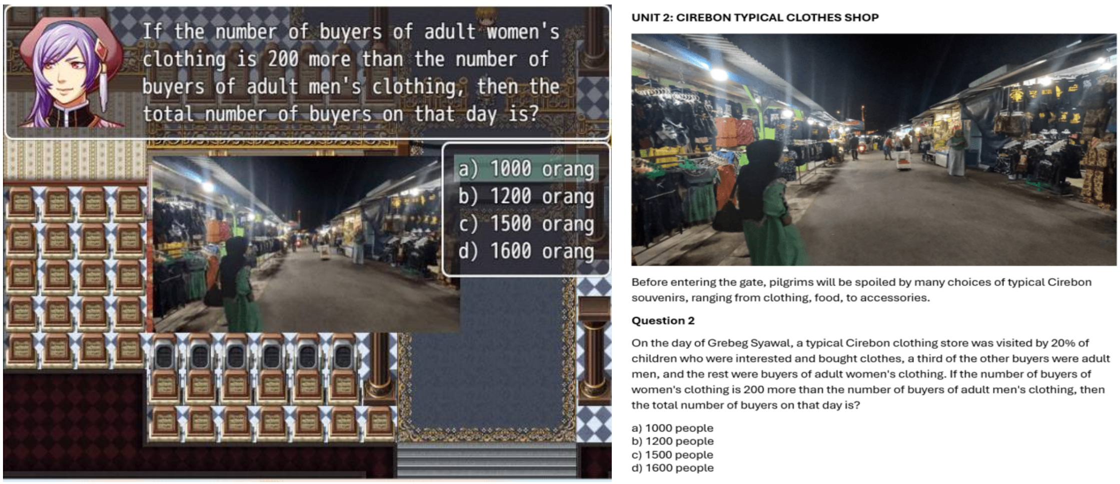
Theoretically, the items developed are qualitatively valid in terms of content, construct, and language, as reflected by the feedbacks and suggestions from the FGD and one-on-one processes (Zulkardi, 2002). At this stage, 4 units and 9 mathematical literacy questions were produced. The revised Prototype 1 was then referred to as Prototype 2.

The validity test results at this stage indicate that the instruments in the learning environment meet the criteria for content, construct, and linguistic validity, confirming their suitability for developing mathematical literacy skills. Content validity ensures alignment between interventions and the intended learning objectives. Construct validity demonstrates that the components of the learning environment are logically interconnected. Linguistic validity ensures the language used in the learning environment is clear, easily understood, and free from ambiguity (Bakker, 2018).

Prototype 2 was subsequently tested during a small group stage with 12 junior high school students from the Cirebon area, representing various abilities. Each student was divided into four heterogeneous teams, each consisting of three people. At this stage, students successfully completed all activities within two lesson hours, approximately 80 minutes. The activities included understanding algebraic material, analyzing example questions, and solving questions in the context of tourism.

Figure 7 shows the results of Prototype 2, which consists of: a) information and explanations related to terms or definitions of variables, constants, terms, coefficients, like terms, and unlike terms. In this section, each concept is explained systematically. Meanwhile, b) presents two formats of questions in the game: a question fragment displayed within the game on the left and a complete version presented in a supporting module on the right.

(a)



(b)

Figure 7. The result of prototyping 2

In the example depicted in Figure 7, section (b), students are tasked with determining the number of buyers in a typical clothes shop in Cirebon. To solve this question, students must analyze the data, represent it in algebraic operations to arrive at the correct answers. According to the PISA framework, this question falls under the 'quantity' category within the context of society. Students are expected to apply their mathematical reasoning to real-world situations. By using algebraic methods, they can effectively interpret the data and derive the solution. This type of problem encourages students to connect mathematical concepts to practical, everyday contexts. The results of students' answers in answering the algebraic questions above can be seen in Figure 8.

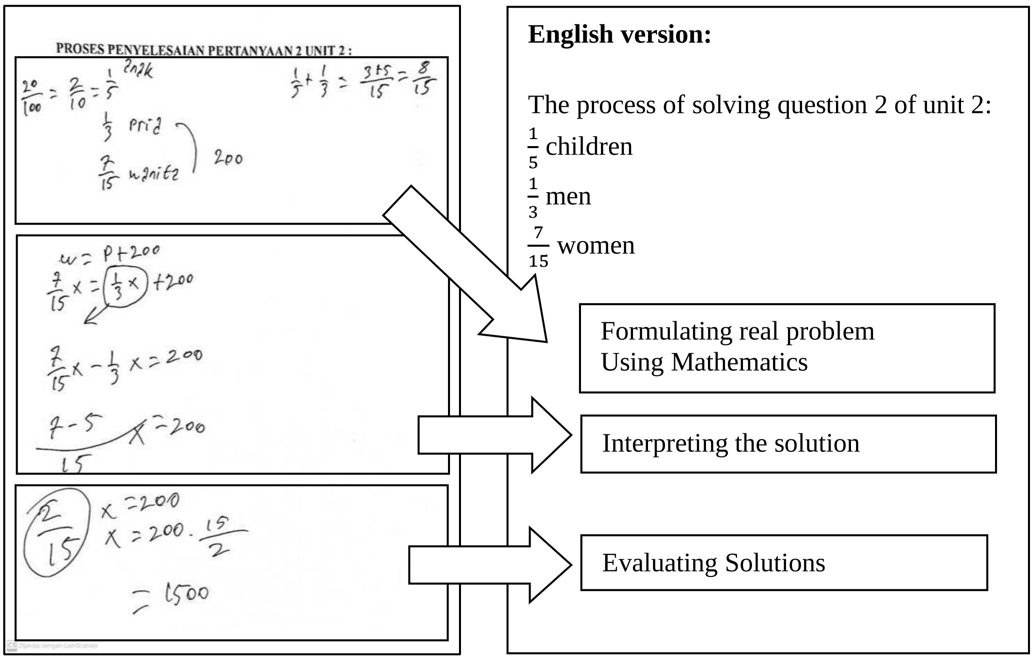


Figure 8. Student' answers to algebraic question

Figure 8 illustrates a student's answer when using the RPG learning environment. To enter the next map, students must first answer the question, and if they fail, the game is over. The provision of the support module is as a student aid that is part of the learning environment to enable students to digest the question again and write down the steps of the work before choosing an answer in the game. Figure 8 depicts the responses given by students. The image illustrates a story problem designed to engage students in a structured thinking process. Students are required to model the story using numerical expressions, identify algebraic properties, recognize patterns, and generalize them, solve problems related to algebra.

The results of observations and interviews in the small group stage revealed that the game-assisted learning environment was considered effective, make it possible to be used for further research. This suggests that this learning environment can be considered for use under normal conditions (Adipat et al., 2021; Fowler et al., 2023).

However, the evaluation results revealed that many students completed the tasks in the game but did not record their solution steps on the provided worksheets. In game-based learning, it is possible for students to answer questions without documenting their steps, taking the risk of failure and restarting the game. This observation highlighted a critical note for the researcher: a significant number of students were unable to complete their answers on the worksheets due to time constraints. As a result, for the next stage of implementation, the researcher will reconsider the trial duration, aligning the planned activities with the testing schedule. This adjustment aims to enhance the outcomes in the field test phase. According to Yusuf & Pattisahusiwa (2020) ensuring the appropriate timing of trials is essential for achieving optimal results.

Assessment

After prototype 3 was produced validly and practically, the next step included the evaluation process which included 5 Guskey levels (Guskey, 2016). In his next work, Guskey (2002) emphasized the importance of following each evaluation stage according to the order of its levels because the five levels in this model are arranged hierarchically, from simple to more complex, where success at the initial level affects the results at the next level. Therefore, this study was conducted following the stages in order without skipping other stages.

The learning environment in this study is a simple learning environment consisting of learning activities designed by teachers using technology, specifically through the development of an educational RPG game as a learning medium. The classroom and computer lab serve as spaces where students can learn and access the game. This definition aligns with Zulkardi (2002) description of a learning environment as a place where the learning process takes place. Furthermore, Phillips et al. (2010) explain that a learning environment also involves the use of technology, teacher-designed learning activities, and assessments that support student learning. Therefore, the assessment in this study focuses on examining the potential impact of the educational RPG game in facilitating student learning.

At level 1 (Participants Reactions), questions focused on whether participants liked the learning being developed by the researcher (Guskey, 2016). Participants' reactions were viewed from the students' enthusiasm during the learning process. Students were able to collaborate with groups, get to know the religious tourism of the tomb of Sunan Gunung Jati, understand algebraic material, and practice solving algebraic problems with the mathematical literacy skills of the PISA framework. According to the results of interviews with students, it can be concluded that they considered the environment being developed very interesting and enjoyable. This is because the environment being implemented is something new and they have never had before. The tendency of students who often feel sleepy during learning was gone after this learning environment was implemented. In addition, they feel that they have gained new knowledge about algebra without realizing that they are studying. Students also gain new knowledge about tourism and culture contained in the context of Sunan Gunung Jati tomb, which has a long history and character values without having to visit the tourist spot directly. This aligns with several studies that the application of interactive media reduces the level of student boredom while learning and increases creativity (Indariani et al., 2019; Kustyarini et al., 2020; Hidayat et al., 2023). Furthermore, the results of level 1 are the basis for evaluating level 2.

The second level pertains to participant learning, which evaluates whether participants have acquired the intended knowledge and skills (Guskey, 2016). This learning is demonstrated through the series of learning processes conducted using the developed instruments. At the start of the activity, students appeared enthusiastic as they engaged with the narrative and map in the game. They proceeded to play the game, observe the materials provided, and document their findings in the module. Students approached the missions with caution, attentively listening to the instructions and diligently solving them by documenting their processes in the supporting module before selecting an answer. When students encountered failure and had to restart, they demonstrated enthusiasm by preparing more effectively. This included engaging in extensive discussions with teammates, thoroughly reviewing the material encountered during the activity, carefully analyzing the mission questions, and avoiding hasty decisions.

At the third level, school support was evident. This level shifts the focus from individual participants to the organizational dimensions critical to the success of the professional learning experience. However, organizational factors can sometimes hinder or obstruct success, even when individual aspects of professional development are implemented effectively (Guskey, 2023). At this stage, the researchers conducted interviews with school officials, including teachers, curriculum coordinators, student affairs representatives, and principals. Overall, the interviews yielded positive responses, indicating the school's interest in the developed environment. Some teachers expressed a desire for the environment to serve as a learning platform for educators, enabling them to practice creating RPG games and designing instruments not only for mathematics lessons but also for subjects like religion, art, and language. In general, the learning environments developed have been designed for teachers and prospective teachers (Zulkardi, 2002; Efriani et al., 2023; Gustiningsi et al., 2024). Consequently, the school's suggestion to further enhance these environments for teachers will be the primary focus of future research on their continued development.

At this level, researchers observe participants from the initial to the final activity. The focus of observation is on the participants' development of new skills in the mathematization process as formulated by PISA. The intended process involves formulating real-world problems, applying mathematics, interpreting solutions, and evaluating outcomes (OECD, 2023a). Observations indicate that after experiencing failure and being penalized (game over), participants began to read more carefully rather than merely guessing when completing missions (formulating problems). Participants were ultimately able to apply mathematics to answer questions and complete missions by documenting their process in the supporting module. Additionally, participants became familiar with the type of PISA questions and were able to explain them to teammates who had difficulty understanding, demonstrating their ability to interpret and evaluate. At the conclusion of the learning, participants who experienced the developed environment eagerly shared what they had learned with other students. Most students also expressed a desire for the environment to be applied to other subjects, not just mathematics.

The fifth level of Guskey's framework focuses on student learning outcomes. This level aims to enhance all aspects of program design, implementation, and follow-up to demonstrate the overall impact of the developed learning environment (Guskey, 2023). These results were obtained during the field test stage, which involved 30 junior high school students from the Cirebon area. The participants were grouped into teams of three, resulting in 10 teams. The teams were randomly assigned, with each team consisting of students with varying levels of ability. Each team was provided with one game application to play together, while each student received an individual supporting module. The analysis focuses on the student learning process within the team and their individual work on the module. The purpose of providing the supporting module is to analyze how students respond to PISA framework questions, which cannot be observed through the game application alone. Overall, the field test activity led to an improvement in students' mathematical literacy skills. This is demonstrated by the fact that 100% of the teams successfully completed the missions in the developed learning environment and advanced to the final map. Additionally, during the learning process, it was observed that students not only played games but also engaged in learning and were able to solve questions effectively (Dai et al., 2023; Saputra et al., 2024; Azzumar & Rosjanuardi, 2024). Students are able to apply mathematical literacy indicators in their learning, including formulating real-world problems, using mathematics, interpreting solutions, and evaluating outcomes.

In Addition, the five levels of Guskey's assessment indicate that the educational game-assisted mathematical literacy learning environment has a significant potential impact on junior high school students. Students derive significant benefits from the developed environment, gaining not only cognitive knowledge but also character values. An example includes the narrative of the philosophical teachings of "Moh Limo" from Sunan Gunung Jati on the final map, as well as the depiction of religious tolerance on the tomb map of Princess Ong Tien Nio, a Ming Dynasty princess from China and the wife of Sunan Gunung Jati. Consistent with this, Miftah et al. (2023) explained that integrating Islamic values into mathematics education can positively impact students' character. The educational game-assisted learning environment, RPG, developed by researchers, currently targets junior high school students, using computers as the learning space and RPG media as the platform for study. It is supported by modules for note-taking and step-by-step guidance in solving problems.

Research on educational game-assisted learning environments has received positive feedback regarding content, construct, and language aspects. It is deemed practical due to its ease of use, accessibility, flexibility, alignment with learning objectives, and potential to enhance mathematical literacy skills. In the future, a valid, practical, and impactful learning environment will serve as the foundation for developing a model of educational game-assisted RPG-based mathematical literacy learning for teachers and for fostering an RPG game community, which is currently underdeveloped in Indonesia. This product positively influences student learning outcomes, particularly in enhancing mathematical literacy skills. Its gamification approach boosts student motivation and engagement, fostering a learning experience that is both enjoyable and intellectually stimulating. The product fosters the development of critical thinking, problem-solving, and mathematical reasoning skills by providing an immediate feedback mechanism, enabling students to independently identify and correct their mistakes. By fulfilling the criteria of validity, practicality, and potential impact, this product lays a solid foundation for further advancements, including the creation of an RPG-based educational game community in Indonesia.

CONCLUSION

The educational game-assisted learning environment developed in this study has shown validity, practicality, and potential impact in enhancing mathematical literacy skills. It is validated in terms of content, construct, and language, ensuring alignment with learning objectives, logical coherence, and clear communication. The product is also practical, offering an intuitive, user-friendly interface that can be easily accessed and customized to meet diverse educational needs. However, this study has several limitations, including its evaluation in a controlled environment and a participant pool limited to middle school students in Cirebon, which may restrict the generalizability of the findings. Additionally, the focus on mathematical literacy leaves the potential for cross-disciplinary applications unexplored. Future research should broaden the participant demographic, integrate real-world classroom settings, and investigate the application of this product across various subjects to enhance its relevance and broader impact.

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