



Development of a Gamification-Based Mathematical Literacy Assessment Instrument for Elementary Education Students

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Abstract

This study aims to develop a valid, practical and effective gamification-based mathematical literacy assessment instrument. This study uses a development design or R&D with a 3-D model consisting of 3 stages: define, design, and develop. 3-D model is a derivative of Thiagarajan's 4-D model, but does not include disseminate stage due to the limitations of the researcher. Data collection techniques used are expert validation techniques, questionnaires and tests. The instruments used are expert validation sheets, student response questionnaire sheets in the form of google forms, and mathematical literacy test questions presented on the gamification platform. The results showed that the mathematical literacy assessment instrument developed was categorized as valid based on the validator's assessment, practical from the results of trials conducted on small groups, and effective as seen from the results of tests given to prospective teacher students. Based on the test results, it is known that 81,58% of PGSD UNY students are in the good category after working on the mathematical literacy assessment instrument. The numeracy.

Keywords: *Instrument; Assessment; Mathematical Literacy; Gamification*

Introduction

We are currently situated in the era of the rapid development of science and technology (S&T), known as the 5.0 industrial revolution. This phenomenon has propelled society towards a concerted effort to enhance educational prowess, aiming to grasp the intricacies of S&T. In this era, the significance of high-quality human resources (HR) proficient in facing the currents of globalization, free markets, and S&T is unequivocal. To confront such temporal challenges, Indonesian society must swiftly reform and thoroughly prepare itself to avoid lagging behind other nations.

One of the essential skills required to enhance HR quality is mathematical literacy. Mathematical literacy and its correlation with mathematical connection skills have been linked to the enhancement of HR quality in Indonesia (Masjaya & Wardono, 2018). Mathematical literacy denotes an individual's ability to formulate, apply, and interpret mathematics in various contexts, including mathematical

reasoning and utilizing concepts, procedures, and facts to describe, explain, or predict a phenomenon (Prabawati, 2018). This skill facilitates understanding the role or function of mathematics in everyday activities.

The importance of mathematical literacy for a nation's progress is evident through the Programme for International Student Assessment (PISA) conducted by the Organization for Economic Cooperation and Development (OECD) every three years since 2000 (Sukmawati et al., 2018). This program assesses students' mathematical literacy, scientific literacy, and reading literacy (Hewi & Shaleh, 2020). One of PISA's objectives is to evaluate students' mathematical literacy (Sukmawati et al., 2018). Through PISA results, the government can discern Indonesian students' mathematical literacy levels and take steps to effect improvements. Mathematical literacy is not only crucial for primary and secondary school students but also for university students, especially prospective teachers. This is because they will become educators for future students (Hasan Basri et al., 2021).

The mathematical literacy or numeracy of prospective teachers remains low (Ayuningtyas & Sukriyah, 2020). This is evident from the analysis of prospective teachers' mathematical literacy at a state university in West Java. The research categorized students into high-capability (M1), moderate-capability (M2), and low-capability (M3) groups. Based on the analysis ranging from levels 1 to 6, M1 scored at level 4, M2 at level 3, and M3 at level 2. This indicates that prospective teachers' mathematical literacy can be deemed insufficient (Prabawati, 2018). Hence, the mathematical literacy of prospective teachers needs further development and enhancement. This can be achieved by more frequent administration of mathematical literacy assessment instruments (Lestariningsih & Lutfianto, 2021). Consequently, they will become accustomed and able to apply them when they become teachers in the future.

In the current digital era, technology-based devices have been extensively integrated into the educational process (Kurniawan et al., 2021). Technology can be applied from learning activities to assessment implementation. Digitalized assessment implementation should no longer solely rely on conventional methods such as pen and paper (Ramadani et al., 2021). Educators can utilize technology as a medium for assessment creation and execution. One method of assessment implementation utilizing technology is through gamification (Wahyuningsih et al., 2022).

Gamification is a learning approach incorporating elements from games or video games to motivate learners in their learning activities and optimize their enjoyment and comfort towards the learning process (Jusuf, 2016). Gamification-based learning possesses several characteristics according to Moncada, including clear learning objectives, offering challenges and opportunities to succeed, permitting failure in the gaming process, using attractive colors and suitable layouts, providing feedback or rewards to players, and having simple and easily comprehensible game rules (Qurrotaini et al., 2021).

Considering the essence and characteristics mentioned, it is apparent that gamification is beneficial for implementation in the learning process. One aspect of the learning process is conducting assessment. Hence, an assessment instrument can be packaged and presented using gamification methods. With gamification, the assessment instrument created and implemented will become more engaging, interactive, and motivating.

Based on the outlined background, the researcher is interested in conducting a developmental study titled "Development of a Gamification-Based Mathematical Literacy Assessment Instrument for Elementary Education Students at Universitas Negeri Yogyakarta." This study aims to develop a valid, practical, and effective mathematical literacy assessment instrument based on gamification. The developed mathematical literacy assessment instrument will be packaged within a gamified platform and subsequently piloted with elementary education students at Universitas Negeri Yogyakarta.

Methods

This research employed the research and development (R&D) method. The product developed in this research is a gamification-based mathematical literacy assessment instrument. The research was conducted from March to May 2022 at Universitas Negeri Yogyakarta (UNY), Faculty of Education Sciences (FIP), in the Elementary Education (PGSD) undergraduate program through online platforms such as Zoom Meeting. The population of this study comprised 38 sixth-semester students enrolled in the PGSD program at UNY. Among the total students, there were 10 male and 28 female students. Sampling was conducted using random sampling with a saturated sampling model, thus including all population members as samples.

This study employed a 3-D model derived from the 4-D development model proposed by Thiagarajan et al. The 4-D model consists of the define, design, develop, and disseminate stages. However, the final stage, disseminate, was not implemented due to limitations. As only three stages were utilized, this research development model is referred to as the 3-D model. This development model was chosen for its suitability and systematic approach in developing learning tools. The learning tool referred to in this study is the mathematical literacy assessment instrument.

Data collection techniques included expert validation, questionnaires, and tests. Research instruments used were expert validation sheets, student response questionnaires, and mathematical literacy test items packaged on the gamification platform. Data analysis techniques in this study aimed to analyze the validity, practicality, and effectiveness of the gamification-based mathematical literacy assessment instrument. Instrument validity was analyzed based on expert validation data (expert validity). In this regard, the developed mathematical literacy assessment instrument was validated by experts in mathematics. Subsequently, the instrument was revised based on the experts' feedback. The instrument was deemed valid if the validator accepted it without any further revisions. If revisions were necessary, the instrument was amended until the validator accepted it without further changes. The values provided by the validator were then analyzed using Aiken's V formula. The analysis results would elucidate the validity or suitability of the developed assessment instrument. Instrument practicality was analyzed based on student response questionnaire results distributed during the small-scale pilot study phase. Meanwhile, the effectiveness of the assessment instrument was analyzed based on data from the main pilot study phase.

Instrument Validity Analysis

The validity of the mathematical literacy assessment instrument was obtained through the analysis of expert validation sheets using Aiken's content validity. Content validity examines experts' assessments and opinions by adopting Aiken's validity formula. Aiken's content validity calculation was used to determine the content validity coefficient of assessment instrument items. The coefficient value or V represents the agreement index regarding the conformity of the items with the indicators to be measured. The Aiken's content validity formula is as follows:

$$V = \frac{\sum s}{n(c - 1)}$$

Where:

- V = content validity coefficient
- S = (score given by the validator) - (minimum validation score possible)
- n = number of items assessed
- c = highest scoring

Note: The range of V values is from 0 to 1. If the V value is greater than 0.5, the item can be considered valid (v).

Instrument Practicality Analysis

In this study, the practicality of the mathematical literacy assessment instrument was determined from the results of instrument testing on a small scale. The practicality of the assessment instrument can be observed through this small-scale test. Through this test, developers can identify which instrument items are good and which are not. Good and less effective assessment instrument items can be discerned from the results and responses of test participants after completing the assessment. Effective assessment instrument items will be used in the large-scale pilot study or main pilot study phase. Meanwhile, less effective assessment instrument items will not be used or will be improved first if they are to be used in the next phase.

Ten undergraduate students from the Elementary Education (PGMI) program at one of the campuses in Sambas district, West Kalimantan province, will be involved in this small-scale pilot study. These subjects were chosen because they were deemed to have similar characteristics to the UNY PGSD students who will be the subjects of the subsequent large-scale pilot study. The similarity lies in both being in the same program of study and semester level. After conducting the small-scale pilot study, developers will distribute response questionnaires to each student to obtain feedback and identify any challenges encountered by students while working on the instrument items.

Instrument Effectiveness Analysis

The effectiveness analysis of the mathematical literacy assessment instrument is determined based on the data obtained from the main pilot study conducted with prospective teachers. Participants in the mathematical literacy assessment are deemed proficient if they individually achieve a score of ≥ 75 . This indicates that the assessment participants have successfully completed the assessment, mastered the competencies, or achieved the learning objectives. Classical mastery is obtained through the number of assessment participants who have successfully completed or achieved the predetermined minimum score, totaling 80% of the total number of assessment participants in a class. This classical mastery serves as a benchmark for the effectiveness of the developed mathematical literacy assessment instrument. After completing the assessment, participants in the main pilot study are also asked to fill out a student response questionnaire distributed in the form of a Google Form. The feedback and inputs provided by the main subjects will be used to refine the assessment instrument before it becomes the final product.

Results and Discussion

A. Results

In the define stage, the researcher conducted a needs analysis and problem analysis. The analysis was carried out through literature review and observation to obtain preliminary data. During this stage, the following data were obtained: 1) mathematical literacy skills are necessary to enhance human resource quality, 2) mathematical literacy skills are not only important for students in schools but also for prospective teacher students who will become educators for future students, 3) the mathematical literacy skills of prospective teacher students are low, 4) prospective teacher students need to be acquainted with and accustomed to mathematical literacy by more frequently creating or working on mathematical literacy assessment instruments, 5) assessment implementation in the current digital era should integrate technology. Findings from the define stage were used to formulate the general objectives of product development. The general objective is to develop a valid, practical, and effective gamification-based mathematical literacy assessment instrument.

In the design stage, the researcher designed questions similar to those in PISA assessments. These questions have more than one way to answer, namely multiple choice, complex multiple choice, short answer, matching, and essay. Subsequently, the researcher analyzed gamification platforms that fit the criteria of the designed mathematical literacy assessment instrument. Based on the analysis results, the platform that fits the criteria of the assessment instrument design is Quizziz. Quizziz is a gamification platform that can be easily accessed through an internet browser. Quizziz is a gamification platform typically used as a medium for quizzes or assessments. On Quizziz, we can create questions with several answer methods, including multiple choice, complex multiple choice, short answer, matching, and essay. Based on these characteristics of Quizziz, there are similarities with the characteristics of the mathematical literacy assessment instrument being developed. Therefore, in the design stage, a mathematical literacy assessment instrument to be packaged on the gamification platform called Quizziz was developed.

In the develop stage, the researcher began developing the mathematical literacy assessment instrument. The development stages were 1) determining basic competencies (KD) and indicators, 2) composing item grids based on KD and indicators, 3) determining the number of questions, and 4) writing questions along with their answer keys. After developing the instrument, the next step was to validate the assessment instrument with experts. If the assessment instrument has been declared valid and there are no further revisions from the experts, then the assessment instrument items are created on the Quizziz platform.

The valid mathematical literacy assessment instrument, packaged in the Quizziz platform, was then piloted with a small group. The purpose of this small-group pilot was to assess the practicality of the gamification-based mathematical literacy assessment instrument that had been validated by experts. After completing the mathematical literacy assessment instrument, small-group pilot students were given response questionnaires. They could provide feedback and input regarding the instrument they had worked on. This feedback and input would be used by the researcher to refine the mathematical literacy assessment instrument before piloting it with the main subjects or groups. After obtaining a valid and practical mathematical literacy assessment instrument, the instrument was piloted with the main subjects, namely 38 sixth-semester PGSD UNY students. This main pilot aimed to determine the effectiveness of the developed gamification-based mathematical literacy assessment instrument.

1. Description of the Validity Analysis Results of the Mathematical Literacy Assessment Instrument by Experts

The validity test for the mathematical literacy assessment instrument was conducted by experts, in this case, mathematics education professors in the PGSD program at UNY. The validators assessed the alignment between content, instrument construction, language used, instructions, and scoring guidelines. The assessment was conducted by assigning scores to each aspect evaluated on a range of 1 – 4 based on a Likert scale. Based on the evaluation by the validators, an analysis was performed to determine the Aiken's index coefficient using the formula proposed by Aiken. The analysis results based on the validator's assessment of the development of the mathematical literacy assessment instrument are presented in Table 1 below.

Table 1. Results of the Validity Analysis of the Mathematical Literacy Assessment Instrument

No	Aspect Validated	V	Category
1.	Using language in accordance with proper grammar	0.93	V
2.	Instructions are written clearly and easy to understand	0.88	V
3.	Mathematical terms used correctly	0.92	V
4.	Item grids can be used as a guide to design mathematical literacy assessment items	0.85	V

5.	Questions given are aligned with mathematical literacy competency indicators	0.90	V
6.	Questions given are suitable for the academic level of PGSD students	0.92	V
7.	Questions encourage students to read	0.95	V
8.	Questions provided for students can utilize basic algorithms, formulas, and clear procedures	0.91	V
9.	Images, graphs, or tables presented are clear and readable	0.82	V
10.	Scoring guidelines are clearly structured to avoid subjectivity in test correction	0.83	V
Average Total Score		0.89	V

Based on Table 1, it is known that the average coefficient of validity is 0.89. This value is above 0.5, indicating that the developed mathematical literacy assessment instrument meets the validity criteria. Therefore, it can be concluded that the developed mathematical literacy assessment instrument is valid and suitable for use in the pilot phase.

2. Description of the Practicality Analysis Results of the Mathematical Literacy Assessment Instrument

To assess the practicality of the mathematical literacy assessment instrument, the instrument was piloted with a small group (Disnawati & Nahak, 2019). The subjects participating in the small-scale pilot comprised 10 sixth-semester PGMI students. This small group consisted of 5 male and 5 female students. These students were chosen because they were in the same academic program and at the same academic level as the main subjects. In this phase, students were asked to complete the mathematical literacy assessment instrument packaged on the Quizziz platform. After completing the assessment, they were requested to provide feedback and suggestions by writing them in a google form distributed to them.

Based on the responses filled out by the pilot students, 9 students stated that the questions in the mathematical literacy assessment instrument were easily understood, while 1 student mentioned difficulty in understanding the questions clearly. They also noted that the assessment instrument had an appealing interface as it was packaged using the Quizziz platform. Additionally, they mentioned that the assessment questions presented could enhance their literacy skills.

The small-scale pilot students not only provided positive feedback on the assessment instrument but also offered negative feedback and several constructive suggestions. They pointed out some shortcomings of the assessment instrument, such as the small size of images and tables in the questions and the short duration allotted for answering each question. Based on these responses, they provided suggestions to the developers to increase the size of images or tables in the questions and to extend the time allocated for each item. These feedback and suggestions were used as input to revise the mathematical literacy assessment instrument before testing it in the main pilot phase.

3. Description of the Effectiveness Results of the Mathematical Literacy Assessment Instrument

The effectiveness of the mathematical literacy assessment instrument was obtained from the main pilot or large-scale trial involving 38 prospective teacher students from the PGSD program at UNY in the sixth semester. Participants completed the assessment instrument through the gamified platform "quizziz" accompanied by the course instructor and researcher. Descriptive analysis of the scores of the prospective teacher students' mathematical literacy assessment can be seen in Table 2 below.

Table 2. Descriptive Analysis of the Results of the Students' Mathematical Literacy Assessment

No.	Parameter	Statistical Value
1.	Research Subjects	38
2.	Number of Participants Passed	31
3.	Number of Participants Not Passed	7
4.	Ideal Score	100
5.	Average	78.82
6.	Standard Deviation	9.62
7.	Score Range	35
8.	Minimum Score	60
9.	Maximum Score	95

Table 2 above explains that the average score obtained by the prospective teacher students in the mathematical literacy assessment was 78.82 out of the ideal score of 100, with a standard deviation of 9.62. Individually, the scores obtained by prospective teacher students ranged from the lowest score of 60 to the highest score of 95. The frequency distribution of the scores obtained by prospective teacher students in the mathematical literacy assessment is shown in Table 3 below.

Table 3. Frequency Distribution of Achievement Results in the Assessment

Score	Category	Frequency	Percentage
$85 \leq S \leq 100$	ST	13	34.2%
$65 \leq S < 85$	T	22	57.9%
$55 \leq S < 65$	S	3	7.9%
$35 \leq S < 55$	R	0	0%
$0 \leq S < 35$	SR	0	0%
Total		38	100%

Based on the scores of the 38 prospective teacher students who took the mathematical literacy assessment, there were 13 students who scored in the range of $85 \leq S \leq 100$, classified as very high category, 22 students scored in the range of $65 \leq S < 85$, classified as high category, and 3 students scored in the range of $55 < S < 65$, classified as medium category. Thus, it can be concluded that the average result of the prospective teacher students' mathematical literacy assessment falls into the high category.

To determine classical mastery, the percentage of students' mathematics literacy assessment results overall should exceed 80%. Table 4 provides a detailed analysis of classical mastery of prospective teacher students' mathematics literacy assessment results.

Table 4. Classical Mastery of Students' Mathematics Literacy Assessment Results

Score	Category	Frequency	Percentage
≥ 75	Tuntas	31	81.58%
< 75	Tidak Tuntas	7	18.42%
Total		38	100%

Table 4 reveals that the number of students who achieved mastery in the assessment, scoring between 75 – 100, amounts to 31 out of 38 students, or 81.58%. Meanwhile, the number of students who

did not achieve mastery, scoring between 0 – 74, is 7 students, or 18.42%. Thus, this data indicates that classical mastery has been attained with the overall percentage of students achieving mastery exceeding 80%.

Data on students' questionnaire responses were obtained through the distribution of questionnaires to 38 prospective teacher students. These response questionnaires were distributed after they completed the mathematics literacy assessment on the gamified platform. In these questionnaires, students were asked to provide feedback on the gamified-based mathematics literacy assessment instrument they had completed. The analysis of students' questionnaire responses can be seen in Table 5 below.

Table 5. Analysis of Students' Questionnaire Response

Aspect	Score	Category
Question Construction	3.4	Good
Question Attractiveness	3.8	Very Good
Question Language	3.5	Very Good
Total	3.52	Very Good

Based on the aforementioned Table 5, it can be observed that according to the responses from prospective teacher students, the mathematics literacy assessment instrument possesses well-constructed, attractive questions with easily understandable language and clear instructions.

The trial of the mathematics literacy assessment instrument with prospective teacher students proceeded smoothly. The assessment participants exhibited great enthusiasm and eagerness in completing the assessment through the gamified platform named "Quizizz." As known, the gamification model allows a group of individuals to engage in a competitive environment. The platform includes a ranking system, encouraging students to compete for the top positions. Below is the documentation of the implementation of the gamified-based mathematics literacy assessment.

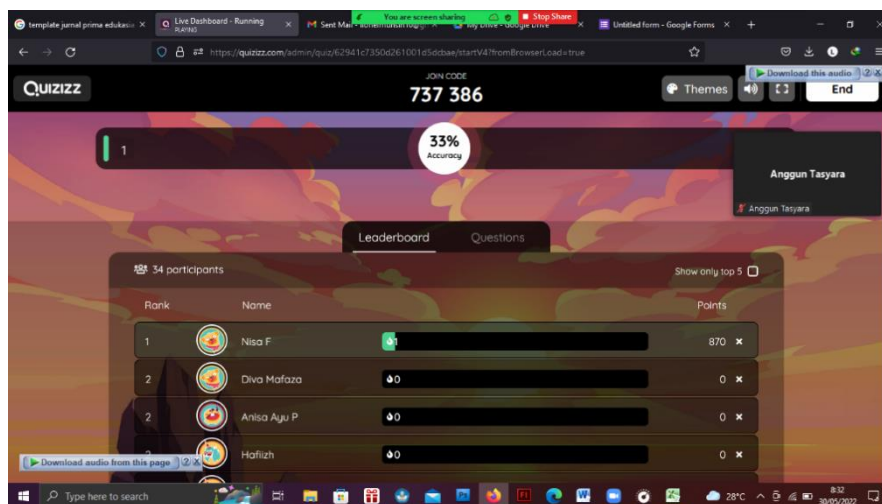


Figure 1. Display of assessment execution from the server computer

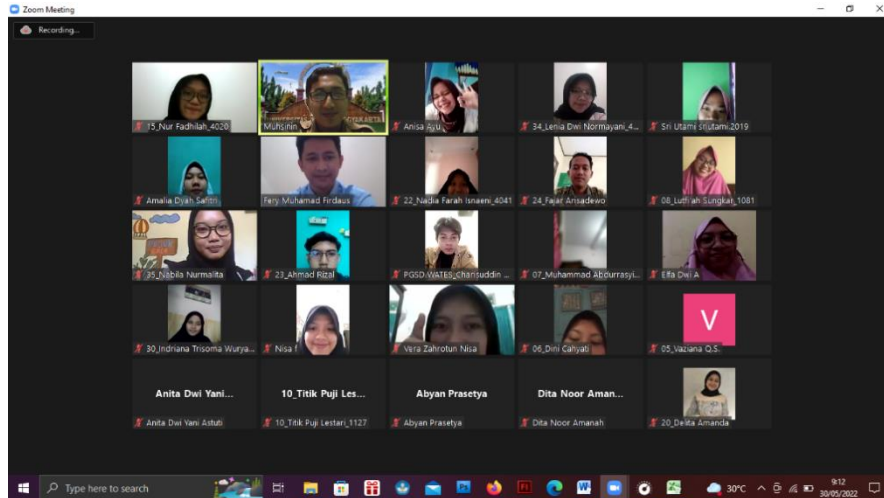


Figure 2. Enthusiasm of Assessment Participants

B. Discussion

The development of gamified-based mathematics literacy assessment instrument was conducted in three stages based on the 3-D model, namely the define, design, and develop stages. This research involved a mathematics education lecturer as an expert validator, 10 PGMI students involved in small group testing, and 38 PGSD students as the main subjects. After undergoing the revision and testing stages, the developed gamified-based mathematics literacy assessment instrument has met the criteria of validity, practicality, and effectiveness. Packaging the mathematics literacy assessment instrument on a gamified platform is novel and engaging for prospective teacher students. This makes the assessment implementation less formal than conventional assessments, resembling a game. This gamified platform also displays rankings and champions, thus motivating students to strive and excel in the assessment to achieve top rankings.

The validity of the mathematics literacy assessment instrument was obtained from expert validation based on aspects such as alignment between content, instrument construction, language used, usage instructions, and scoring guidelines. The analysis of validation data from experts regarding the mathematics literacy assessment instrument, as shown in Table 1, indicates that the average expert assessment for all aspects meets the validity criteria. The expert assessment of this assessment instrument has not reached the maximum score; thus, revisions were made based on suggestions, corrections, and considerations from the validator. After revision, the development of the mathematics literacy assessment instrument was declared valid and ready for small group testing and main testing phases.

The practicality of the mathematics literacy assessment instrument was determined based on small group testing. This small group consisted of 10 PGMI students who have similar characteristics to the PGSD students at UNY as the main testing subjects. After the testing participants completed the assessment, they were asked to provide feedback and input on the instrument through a Google Form. Based on the feedback from the small group testing participants, most items of the mathematics literacy assessment instrument were deemed satisfactory. According to the participants, the mathematics literacy assessment instrument uses appropriate and easily understandable language. The visuals and colors are also attractive, and the items of the instrument encourage them to engage in literacy activities. According to Chamalah (2020), attractive visuals and colors can enhance literacy for students. However, shortcomings were also identified in some items of the instrument according to the testing participants. These shortcomings were related to the small size of question images and tables, making it difficult for participants to observe the presented images or tables. Another challenge they faced was the relatively

short time duration provided for each question item. These feedback and inputs serve as considerations for researchers to make improvements and refinements to the instrument. After making improvements, the mathematics literacy assessment instrument was tested on the main subjects.

Meanwhile, the effectiveness of the mathematics literacy assessment instrument is based on the analysis of results from large-scale testing or main testing with prospective teacher students. Table 3 shows the average results of students' mathematics literacy assessment falling into the high category. Classical mastery refers to the number of students scoring ≥ 75 , which amounts to 81.58%. The analysis of classical mastery is displayed in the previous Table 4. The number of students who achieved mastery, scoring between 75 – 100, is 31 out of 38 students, or 81.58%, while the number of students who did not achieve mastery, or scored between 0 – 74, is 3 students, or 18.42%. This data indicates that classical mastery has been achieved, with the overall assessment participants obtaining scores exceeding 80%. Based on these results, the mathematics literacy assessment instrument can be considered effective.

Conclusion

Based on the research and development results, it can be concluded that the mathematics literacy assessment instrument is valid, practical, and effective. The validity of the instrument is supported by the validation analysis results conducted by experts, with a score of 0.89 falling into the high validity category. Therefore, based on these validation results, the mathematics literacy assessment instrument is deemed valid and suitable for use in the testing phase. The practicality of the instrument is obtained from the results of small group testing, involving 10 students. Based on the analysis of the testing results, the mathematics literacy assessment instrument proves to be practical and suitable for use in large-scale testing or main testing. Meanwhile, the effectiveness of the mathematics literacy assessment instrument is assessed based on the results of large-scale testing or main testing involving 38 PGSD students as the research sample. According to the analysis results, it can be concluded that the gamified-based mathematics literacy assessment instrument tested on prospective teacher students falls into the effective category. This is evident from the assessment results of students scoring > 75 , amounting to 31 students or 81.58%. Prospective teacher students evaluate the mathematics literacy assessment instrument as highly engaging, with clear usage instructions and easy to understand. This is reflected in the results of the distribution of student response questionnaires, with the majority providing positive responses.

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