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Development of Mathematical Literacy Tests to Measure Student's Reasoning and Representation Skills

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ABSTRAK

Penelitian ini bertujuan untuk menghasilkan tes literasi matematika untuk mengukur penalaran dan representasi matematis siswa pada materi SPLDV yang valid dan memiliki karakteristik yang baik. Penelitian ini mengadopsi prosedur pengembangan R&D, yakni pengumpulan informasi, pengembangan produk, dan uji coba & revisi awal. Instrumen yang digunakan berupa lembar validasi. Analisis data menggunakan Microsoft Excel dan SPSS 26. Hasil penelitian menunjukkan bahwa, melalui validasi ahli, instrumen tes yang dikembangkan dapat digunakan untuk mengukur penalaran dan representasi matematis siswa dan butir soal terkategori valid, reliabel, tingkat kesukaran sedang dan tinggi, serta daya pembedanya baik.

Kata Kunci: Penelitian Pengembangan; Tes Literasi Matematika; Penalaran Matematis; Representasi Matematis.

ABSTRACT

This study aims to produce a mathematical literacy test to measure students' mathematical reasoning and representation on system of linear equations in two variables (SLETV) material that is valid and has good characteristics. This research adopts R&D development procedures, namely information gathering, product development, and initial trials & revisions. The instrument used was a validation sheet. Data analysis using Microsoft Excel and SPSS 26. The results of the study showed that, through expert validation, the developed test instrument can be used to measure students' mathematical reasoning and representation and the test items are categorized as valid, reliable, moderate and high levels of difficulty, and have good discriminatory power.

Keywords: Development Research; Mathematical Literacy Test; Mathematical Reasoning; Mathematical Representation.

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1. INTRODUCTION

In the Principles and Standards for School Mathematics 2000, five standards describe the relationship between mathematical understanding and fundamental skills that students need to perform effectively in the 21st century (NCTM, 2000). Moreover, these essential skills help individuals comprehend mathematics' role in daily life and make the appropriate conclusions and decisions needed in the 21st century (N. Sari et al., 2022, 2023). The skills, students need to have, are covered in process standards including problem-solving, reasoning and proof, communication, connections, and representation.

Reasoning skills is a process of thinking to understand the notions and concepts that comprise a procedure (Bieda et al., 2014) and the process of thinking to form conclusions based on facts or premises that are assumed to be true (Hasanah et al., 2019; Nurjanah et al., 2020). Furthermore, reasoning skills is the process of taking information, and then comparing it with prior knowledge to reach a conclusion. Students through mathematical reasoning skills gain new knowledge in the form of a conclusion on the problems they face. Several aspects are measured in mathematical reasoning. Below are the indicators and aspects of mathematical reasoning in this research.

Table 1. The Indicators of Mathematical Reasoning

Indicators	Aspects that are measured
Identifying observed patterns and structures	Identifying the pattern and structure of a statement
	Using the discovered pattern and structure to solve the problem
Proposing assumptions and conjectures	Making an assumption before doing an analysis
	Making an argument for the stated assumption
Concluding with a logical argument	Create a rational argument to solve the problem
	Drawing a conclusion from the answers obtained

Based on the achievements of learning outcomes in the process of learning mathematics, the skills that suggests to be formed besides reasoning skill is representation skill. Mathematical representation is the skills to communicate mathematical statements in a variety of forms, including equations, graphs, tables, drawings, symbols, and notations (Mawaddah & Anisah, 2015). Representation plays a role as a model or as a substitute for a problem that is used to find a solution (Nuraeni et al., 2020). The student's representation reflects their ideas and mathematical thinking as they work towards solving a problem (Masitoh & Prabawanto, 2015). Therefore, mathematical representation skills are needed to present various kinds of mathematical concepts or ideas that students receive (Hernawati, 2016). The importance of mathematical representation skills makes representation an essential element that needs to be trained to support understanding of mathematical concepts (Nurfitriyanti et al., 2020). The following are aspects and indicators of mathematical representation in this research.

Table 2. The Indicators of Mathematical Representation

Indicators	Aspects that are measured
Symbolic representation: a mathematical equation or expression	Create problem situations with equations or mathematical expressions based on the information provided
	Solve given problems using equations or mathematical expressions
Verbal representation: word or written text	Create problem situations with words based on given data or representations
	Solve the given problem using words or written text
Visual representation: drawings, tables, diagrams, or graphs	Create problem situations with drawing, tables, diagrams, or graphs based on the information provided
	Solve given problems using diagrams, tables, graphs, or drawing

Mathematical reasoning and representation abilities are basic skills that must be mastered in mathematical literacy (Muzaki & Masjudin, 2019). Mathematical literacy can help someone understand mathematics' role in daily life (Masfufah & Afriansyah, 2022). This is because mathematics has a lot of connections in daily life, so it requires understanding literacy to complete it (Aini & Suparman, 2019). In simple terms, mathematical literacy is knowledge about mathematics and how to apply it in daily life (Sari et al., 2021). Mathematical literacy has seven components including communication, mathematizing, representation, reasoning, and argument, devising strategies for solving problems, using symbolic, formal, and technical language and operations, and using mathematical tools (OECD, 2019). Based on this, it can be seen that mathematical reasoning and mathematical representation skills are related to mathematical literacy.

However, in fact the level of students' mathematical literacy skills is still relatively low (Iqrima, Zulkarnain, & Kamaliyah, 2023; Jayanti & Cesaria, 2024). This is shown in the result of international studies PISA, where students' mathematical literacy scores are very low with 379 out of the average score 489 (Schleicher, 2019). The result of the 2015 Trends in International Mathematics and Science Study (TIMSS) also shows that Indonesia students' mathematics quality is still low with score of 397 and ranked 46th out of 51 countries (Retnowati & Ekayanti, 2020). Moreover, other result also show that students' mathematical reasoning skills are still very low (Suprihatin et al., 2018; Iswanto & Faradillah, 2023). Pambudi et al. (2021) shows that the average of mathematical reasoning skill is 3 (maximum score 20) and average of mathematical representation skill is 10,5 (maximum score 22), which were relatively low.

One of the reasons why students' level of reasoning skills and mathematical representation is weak is that teachers still give monotonous problems (Rismen, Mardiyah, & Puspita, 2020; Suningsih & Istiani, 2021). Moreover, teachers also pay less attention to appropriate criteria when creating problems. The test that they made is more on cognitive aspects only. Many problems, used in learning, only require students to remember the material

rather than to think in higher level (Alfiatin & Oktiningrum, 2019). This alligns with what Oktiningrum et al. (2016) said that since Indonesian students are not accustomed to using critical thinking to solve mathematical issues, their mathematical literacy is lower than that of students in other nations. Another problem is the lack of availability of specially designed problems that suit students' potential to use higher-level thinking skills such as reasoning and representation abilities (Anisah et al., 2011).

Based on these problems, the anticipation or solution that can be done is to develop a test that can facilitate students to think at a higher level. In development research by (Anisah et al., 2011), the results obtained that the PISA model problems developed have a potential effect on students' mathematical reasoning skills. The research by Sari et al. (2017) has also developed an assessment instrument that is valid, reliable, and capable of measuring students' mathematical representation skills. However, there is no research yet that focuses on developing literacy-based tests that can measure students' mathematical reasoning and representation skills.

Based on the previous explanation, this research aims to develop a mathematical literacy test to measure students' mathematical reasoning and representation skills. The hope of this research is to make a contribution to mathematics learning and provide variations of previously existing tests, especially those related to literacy tests that measure reasoning and representation skills, and to find out the validity and characteristics of the problem-solving and mathematical reasoning skills tests that have been developed.

2. METHOD

The method used is research and development (R&D). The development model employed in this study is a major development model produced by Borg & Gall (1983) which is modified with various other models such as Dick and Carey's model (Dick et al., 2005) and Kemp's model (Kemp et al., 1994). Further changes to the development paradigm culminated in the creation of a new development model known as RRD (Real Research and Development). The RRD model consists of five major stages, which are as follows: (1) collecting information, which includes the definition of abilities and the setting of objectives; (2) developing the product, specifically the creation of the mathematical literacy test; (3) testing the preliminary and revision; the validator reviews the mathematical literacy test to get comments in terms of content, construct, and language; (4) testing the operational test and revision; this stage was a test phase at predetermined schools, followed by the final mathematical literacy test; and (5) doing dissemination and implementation; the tested final mathematical literacy test is disseminated.

The research participants were 31 ninth-grade students from SMP N 17 Palembang, South Sumatra, Indonesia. The research instruments used were validation sheets and description

test instruments. The validity sheet data collected from the validator was used as the data gathering technique in this study, especially in the preliminary test and revision stage. The validator will provide an assessment by scoring the current assessment components of the test with a checkmark from very good (5), good (4), enough (3), less (2), and very less (1). After the validator assesses the current assessment components of the test, the total score of each validator is calculated as a percentage using the formula below, and categorized according to the eligibility category for testing listed in Table 3 (Lestari et al., 2021).

$$P = \frac{\sum x_i}{N} \times 100\%$$

Description:

P = Percentage

$\sum x_i$ = Total of score

N = Maximum score

Table 3. Eligibility Category for the Test

Score Interval	Category
81% - 100%	Very Eligible
61% - 80%	Eligible
41% - 60%	Fairly Eligible
21% - 40%	Not Eligible
0% - 20%	Very Inappropriate

In the testing operational tests and revision stage, the revised mathematical literacy tests were administered to students to examine the validity, reliability, level of difficulty, and discriminatory power of the item tests. Item test validity and reliability were analyzed using SPSS 26. The item tests' difficulty level and discriminatory power were analyzed using Microsoft Excel. The item test validity uses the product moment correlation formula as follows.

$$r_{xy} = \frac{N\sum XY - \sum X \sum Y}{\sqrt{(N\sum X^2 - (\sum X)^2)(N\sum Y^2 - (\sum Y^2 - (\sum Y)^2)}}$$

Description:

r_{xy} = Correlation coefficient of each item

N = The number of subjects

X = Item test score

Y = Score total

The calculated value of each item is then compared with critical value. If with a significant level of 5%, the item is valid, and vice versa. Next, the reliability of the mathematical literacy test was based on Cronbach's Alpha formula as follows.

$$r_{11} = \left(\frac{n}{n-1}\right)\left(1 - \frac{\sum {\sigma_i}^2}{{\sigma_i}^2}\right)$$

Description:

r_{11} = Test reliability

n = Number of item test

$\sum \sigma_i^2$ = Total score variance of each item

σ_i^2 = Total variance

The calculated are compared with critical value. The mathematical literacy test is regarded to be reliable if it is greater than 0.6 (Widiansah et al., 2019; Purwanto et al., 2021; Singh et al., 2023). Afterward, the mathematical literacy test' s difficulty level (DL) is known by calculating the score using the following formula.

$$DL = \frac{\bar{X}}{maximum\ score}$$

Description:

DL = Difficulty level of each item

$\bar{X}$ = The average of each item

The score will be categorized in three category as in Table 4 (Fitriani, 2021).

Table 4. The Category of Difficulty Level

Difficulty level (DL)	Category
0.00 DL 0.30	Difficult
0.31 DL 0.70	Moderate
0.71 DL 1.00	Easy

The distinguishing power of each item is determined by using formula as below.

$$DP = \frac{\bar{X}_A - \bar{X}_B}{Max\ Score}$$

Description:

DP = Distinguishing power of each item

$\bar{X}_A$ = Higher group average

$\bar{X}_B$ = Lower group average

The category of distinguishing power for each item is using the category by Sahlan et al. (2023) from Table 5.

Table 5. The Distinguishing Power Category

Distinguishing Power	Category
0.70 DP 1.00	Best
0.40 DP 0.70	Good
0.20 DP 0.40	Sufficient
0.00 DP 0.20	Bad
DP 0.00	Worst

A good test instrument meets various characteristics, including good item validity, reliability, varying levels of item difficulty, and the different power of items that are capable to

distinguish between smart students and students who are unable to respond to the items (Fauziana & Wulansari, 2021).

3. RESULT AND DISCUSSION

a. Collecting Information

At this stage, an analysis of the definitions and indicators of reasoning skills and representation skills is carried out, analysis of the test material to be developed, and analysis of problems that can be raised as context for the mathematical literacy test to be developed. After the analysis was carried out, some data was collected as a basis for developing a mathematical literacy test instrument to measure students' mathematical reasoning and representation abilities. First, based on the definition and previous literature review, indicators of reasoning skills and indicators of representation can be seen in Table 1 and Table 2. Second, the test that will be developed is used for material on SLETV with indicators of learning objectives including: (1) identifying SLETV, (2) creating models of SLETV from contextual problems, (3) solving contextual problems regarding SLETV. Third, the problem that will be used as context is a personal context and a work context. The test instrument developed was in the form of 3 essay problems and a scoring rubric based on reasoning skills and mathematical representation.

b. Developing the Product

At this stage, a mathematical literacy test instrument to measure reasoning and representation abilities was prepared as an initial development draft. The test instrument that was created consisted of three SLETV essays. The outcomes of the data gathering in the preceding step serve as the basis for the instrument's preparation. Figure 1 shows an example of a test tool for mathematical literacy that assesses representation and reasoning skills.

Figure 1. First Draft of the Mathematical Literacy Test Instrument

From Figure 1, the context used is a personal context regarding music concert tickets. The indicator in this problem is that students can determine whether more than 100 gold class tickets are sold. This problem is intended to measure reasoning abilities in conveying conjecture indicators and representation abilities on the visual representation aspect. Initially, It is expected of students to be able to resolve this issue using graphic methods.

c. Testing the Preliminary and Revision

The preliminary and revision testing stages begin with validation of the mathematical literacy test instrument developed according to the content, construct and language characteristics described in the expert validation sheet. Two Mathematics education lecturers are the expert validators in this research. The first validator is a lecturer from Jambi University and the second validator is a lecturer from Sriwijaya University. Expert validators provide assessments in the form of scores, comments, and suggestions as feedback for the problems. These become the basis for revising the test instrument. Their feedback can be seen in the Table 6.

Table 6. Comments and Suggestion from Validators

Problem Number	Comments and Suggestion
1	From problem 1 the reader assumes that all novels have the same price and all comics have the same price, or that Dio and Raisyah bought comics and novels with the same title. However, in the field, the prices of novels vary depending on the author and the thickness of the novel.
2	• It should be corrected to "Look at Figure 1 which is a brochure for a music concert". • Add Image number and caption. • The music concert with the brochure in Figure 1 sold out … … … …
3	• Create image numbers and captions. • Mall plaza should be named. • It would be better to name it mall plaza A, or another letter. • On one day there were 100 vehicles consisting of cars and motorbikes parked at mall plaza A with rates as in Figure 2.

Based on Table 6, the test instrument is then revised and assessed by the validator. The mathematical literacy tests before and after revision can be seen in Table 7.

Table 7. The Mathematical Literacy Test Before and After Revision

Problem Number	Before Revision	After Revision
1	1. Look to the following statements. (i) Dio and Raisyah went to the bookstore together. Arriving at the bookstore, Dio bought four comics and two novels for a total price of IDR175.000 while Raisyah bought one comic and three novels for a total price of IDR120.000. (ii) A cake shop sells cakes and pastries. This week the cake shop succeeded in selling 100 cakes and 180 pastries and earned an income of IDR14.000.000. (iii) Azzam's blocks are three times as many as Varo's blocks. The total of Azzam and Varo blocks is 200 pieces. (a) Create a mathematical model from the three statements above. (b) Which statements can form a system of linear equations in two variables? Explain.	1. Look to the following statements. (i) Dio and Raisyah went to the painting shop together. Arriving at the shop, Dio bought four markers and two paint palettes for a total price of IDR55.000 while Raisyah bought three markers and one paint palette for a total price of IDR40.000. (ii) A cake shop sells cakes and pastries. This week the cake shop succeeded in selling 100 cakes and 180 pastries and earned an income of IDR14.000.000. (iii) Azzam's blocks are three times as many as Varo's blocks. The total of Azzam and Varo blocks is 200 pieces. a. Create a mathematical model from the three statements above. b. Which statements can form a system of linear equations in two variables? Explain.
2	 2. The music concert successfully sold out all tickets with total sales of IDR33.000.000. a. Are the gold tickets provided by the committee more than 100? b. Give your reasons! (you can use one of the SLETV solving methods).	 2. The music concert successfully sold out all tickets with total sales of IDR33.000.000. a. Are the gold tickets provided by the committee more than 100? b. Give your reasons! (you can use one of the SLETV solving methods).
3	 3. One day, there were 100 vehicles consisting of cars and motorcycles parked in the mall plaza. The total number of wheels for the total vehicle was 320. If the vehicle pays for parking according to the specified cost, then how much parking money does the mall plaza get that day? Solve using the graphic method.	3. Look at the mall plaza A's parking cost information in Figure 2.  **Figure 2. Mall Plaza A Parking Cost Bochure** On one day there were 100 vehicles consisting of cars and motorbikes parked at mall plaza A with the cost as in Figure 2. The total number of wheels for the total vehicle was 320. If the vehicle pays for parking according to the specified cost, then how much parking money does the mall plaza get that day? Solve using the graphic method.

The score analysis result and the validity percentage of the revised mathematical literacy test can be seen in Table 8.

Table 8. Score Results from Validation of Mathematical Literacy Tests to Measure Reasoning and Representation Abilities

Validators	Content	Construct	Language
1	100%	98%	100%
2	97%	100%	100%
Average	98%	99%	100%
Category	Very Eligible	Very Eligible	Very Eligible

Table 8 shows that the mathematical literacy test is very eligible from the content, construct and language aspects of 98%, 99%, and 100% respectively. The highest percentage is from language aspect, which means that this test is considered not to make students confused in understanding the problem instructions.

d. Testing the Operational Test and Revision

At this point, the test instrument was tested on students after passing the expert validity test. The reasoning and representation skills scoring criteria is then used to evaluate the students' responses. Table 9 displays the findings of the item validity and reliability tests.

Table 9. Item Validity and Reliability Test Results

Problem Number	Value of r	Critical Value	Criteria of Validity	Cronbach' s Alpha	Criteria of Reliability
1	0.642	0.05	Valid	0.767	High reliability
2	0.631		Valid		
3	0.804		Valid		

From Table 9, it can be seen that the value of r for all item tests is more than 0.05. It means that all problems or items are valid. The Cronbach' s Alpha is 0.767, which is greater than 0.6 so that the mathematical literacy tests to measure reasoning and representation skills are reliable. Afterward, Table 10 shows the results of the calculations used in the difficulty level and distinguishing power tests.

Table 10. Difficulty Level and Discriminatory Power Test Results

Problem Number	Calculation Value	Criteria of Difficulty Level	Calculation Value	Category of Discriminatory Power
1	0.57	Moderate	0.57	Good
2	0.29	Difficult	0.44	Good
3	0.34	Difficult	0.798	Best

Table 10 shows that one problem is in the moderate level (number 1) and two problems are in the difficult level (number 2 and 3). Table 10 shows that the discriminatory power tests are 0.57, 0.44, and 0.798 for problem number 1, 2, and 3, respectively. Based on the category from Table 5, problem number 1 and 2 are in good category while problem number 3 is in best category. The created test instrument performed well in terms of validity, reliability, level of difficulty, and distinguishing power.

e. Doing Dissemination and Implementation

At this last stage, an article is being written to spread information about developing a valid mathematical literacy test to assess students' reasoning and representation skills. After going through the five main stages of the RRD model, a set of literacy test items was developed is valid, reliable, has varying levels of item difficulty, and contains items with different power that are capable of distinguishing between smart students and students who are unable to respond

to the items. As stated by Fauziana & Wulansari (2021), test item can be used to evaluate students if has strong validity, high reliability, a range of difficulty levels across the items, and the skills to differentiate between high-performing students and those who struggle. So, this test is capable of measuring students' mathematical reasoning and representation skills.

Based on the results of the validity test, the r value for each test item was obtained sequentially of 0.642, 0.631, and 0.804. This means that the r value for all test items is more than the critical value of 0.05 and all items are valid. Then, the results of the reliability test showed that Cronbach's Alpha of 0.767 was greater than 0.6 so that the mathematical literacy test was reliable (Widiansah et al., 2019; Purwanto et al., 2021; Singh et al., 2023). Based on the results of the difficulty level test, the results showed that problem number 1 was at a moderate level while problems number 2 and 3 were at a difficult level. Finally, the discriminative power test is 0.57, 0.44, and 0.798 for items 1, 2, and 3. This means that items 1 and 2 are in the good category while item 3 is in the best category (Fitriani, 2021). However, the mathematical literacy test to measure reasoning and representation abilities is valid and reliable.

This mathematical literacy problem is designed to measure students' mathematical reasoning and representation abilities by linking mathematical concepts to daily situations. According to (Vebrian et al., 2021), literacy problems require students to think critically and logically in solving contextual problems, thus encouraging them to develop reasoning skills. The problems are designed according to the reasoning indicators, such as recognizing patterns, making assumptions and conclusions. In accordance with the statement of Huda et al. (2024) that reasoning abilities can be measured effectively if the problems used are designed to bring out students' thinking processes according to relevant indicators.

In addition, this mathematical literacy problem was also developed to measure students' mathematical representation abilities. Contextual mathematical literacy problems require students to present information or solutions using various forms of representation such as graphs, mathematical models, and equations. In line with the Schleicher (2019) that students' skills to convert real-world issues into mathematical symbols can be assessed through the use of context. Good mathematical literacy problems not only ask for final answers, but also a representation process that shows how students understand and solve problems (Fajriah et al., 2020). Therefore, the problems designed are able to provide in-depth insight into students' skills to reason logically and represent mathematical ideas effectively.

4. CONCLUSION

Based on item validity test, all problems or items are valid with the value of r for all items are more than 0.05. Next, the reliability tests result shows that the Cronbach's Alpha is greater than 0.6 so that the mathematical literacy tests to measure reasoning and representation skills

are reliable. According to the results of the difficulty level test, from the three problem of mathematical literacy test, one problem is in the moderate level (number 1) and two problems are in the difficult level (number 2 and 3). Then distinguishing power test shows that problem number 1 and 2 are in good category while problem number 3 is in best category. Therefore, based on the result of validity test, reliability tests, difficulty level test, and distinguishing power test, the created test instrument performed well in terms of validity, reliability, level of difficulty, and distinguishing power and can be used to measure students' mathematical reasoning and representation skills.

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