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Development of Mathematical Literacy Instruments with Graded Response Model for Grade VII Junior High School Students

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Abstract

This research aims to develop a mathematical literacy instrument in the form of a description for junior high school students with a Graded Response Model (GRM) approach. This research method uses development approaches (R&D), with instrument development using a formative research model which includes preliminary stages, self-evaluation, and formative evaluation. The instruments are arranged in three series of questions, each containing 10 questions of description. The empirical trial involved 160 students in grade VII. The analysis of question items is carried out by applying GRM. The results of the research with field trials showed that: (1) all question items were declared valid; (2) internal consistency is categorized as good; (3) the reliability of the instrument is excellent which indicates stability in measurement; (4) the differential power index is categorized well where the question items in each series are made able to distinguish the upper and lower group of students; (5) the level of difficulty varies so that it can measure ability over a wide range; and (6) the probability of answering correctly according to GRM increases as the ability of each assessment category increases. The results of the concurrent validity test through SEM-PLS showed that series three was significantly related to mathematics learning outcomes with a path coefficient of 0.270 and ϑ=-3 hingga ϑ=3a p-value of 0.000. An R2 value of 0.132 indicates that the SEM-PLS model with three-series instruments is able to explain 13.2% variation in mathematics learning outcomes. Series one and series two are not significant because the p-value obtained is 0.069 and 0.070 respectively. Based on these results, the developed instrument was declared feasible to be used to provide an overview of the mathematical literacy ability of junior high school students.

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INTRODUCTION

The progress of the world of education, which has entered the 21st century, poses its own challenges that must be faced. One of the relevant competencies developed in the 21st century is mathematical literacy. Mathematical literacy trains individuals to think analytically, question assumptions, and evaluate results based on facts (Syamsuri & Pujiastuti, 2024). Mathematical literacy is a basic skill needed by individuals in facing the challenges of an increasingly complex world where math-based data and information are an integral part of decision-making. According to *Organisation for Economic Corporation and Development* (OECD), literacy includes mathematical reasoning and the ability to use mathematical concepts, processes, data, and mathematical functions to draw, interpret, and predict phenomena (Monica et al., 2022).

Several studies show that the mathematical literacy of students in Indonesia is still categorized as low. Results *Programme for International Student Assessment* (PISA) carried out by the OECD shows that the mathematical literacy achievement of Indonesian students is still relatively low. In PISA 2022, Indonesia's average score decreased compared to the previous cycle and was below the OECD average (OECD, 2023). The results of the PISA study (*Programme for International Student Assesment*) reported that the mathematical literacy ability of students in Indonesia was in the 76th position out of 79 countries participating in the test (Lestari & Effendi, 2022). In line with The results of Widianti and Hidayati's (2021) research show that the mathematical literacy ability of students in the level 1 category has a percentage of 62.5%, level 2 with a percentage of 21.9%, and level 3 with a percentage of 9.7%. These results show that students' mathematical literacy skills are still at level 1 where this ability refers to solving problems with routine procedures and basic algorithms (Widianti & Hidayati, 2021).

The low mathematical literacy ability of students is influenced by several factors, one of which is routine in learning, namely the giving and discussion of questions that only require them to do routine problems with direct commands. Another factor that affects the lack of familiarity of students answering questions characteristic of mathematical literacy is the lack of provision of mathematical literacy instruments in schools which is associated with the context of students' lives. During the mathematics learning process, teachers generally focus too much on practicing questions that are procedural and mechanistic, explaining concepts in an informative way, providing sample questions, and giving practice questions that resemble examples of questions

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that have been given before. These learning activities are not effective in fulfilling the development of mathematical problem-solving, reasoning, connection, and communication skills possessed by students. As a result, students' high-level cognitive abilities will be weak because the usual learning activities only encourage them to think at a certain level low level (Aida et al., 2017).

One of the efforts to achieve optimal learning goals is to improve the quality of the instruments used by teachers so that they can encourage the development of students' abilities. The decision taken will not be correct if it is based on inaccurate data. Therefore, instruments play an important role in improving the quality of learning and function to turn facts into data that can be analyzed.

However, the reality in the field is that teachers have not been optimal in developing learning outcome assessment process instruments in schools but only use the questions contained in the supporting books. The instruments used tend to lead to *content-based* rather than *context-based* where mathematical assessment instruments still focus on measuring mastery of material or mathematical content directly such as definitions, formulas, and simple procedures. Therefore, it is necessary to develop mathematical assessment instruments that are packaged in a mathematical literacy model.

In maximizing the improvement of students' thinking skills, it is necessary to make modifications to the measuring tool. The type of instrument to be developed in this study is a mathematical literacy instrument arranged with a level of difficulty and tiered scoring. This type of instrument is one of the alternatives that can be used to improve students' mathematical literacy skills. The development of mathematical literacy instruments with the type of graded description questions is not considered to be accurate and informative enough without being supported by the right scoring method. Usually, questions in the form of descriptions will be done with polynomial scores where the score is stratified (*Graded*) more than two categories are given according to certain criteria (Benefit & Anasha, 2013). One of the models used in modern measurement theory is *Graded Response Model* (GRM). Use of the GRM scoring model (*Graded Response Model*) is aimed at polynomial data where the reliability estimation results are higher than the GPCM scoring model (*Generalized Partial Credit Model*) is evidenced by a comparative study conducted by Ningsih and Isnani where the results of the estimated reliability in the GRM score are 0.289 and in the GPCM score is 0.278 so that the difference is 0.011 (Ningsih & Isnani, 2010).

In this study, the researcher chose to examine the development of mathematical literacy instruments for grade VII junior high school on integer and rational materials, algebra, one-

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variable linear equations and inequalities, and ratios/comparisons. The reason is that the materials are taken in the first semester (odd) where the materials can be used as a basis for learning at the junior high level. These materials are materials that are interrelated with each other. For example, in explaining the concept of linear equations and inequalities of two variables, there will be a concept of numbers written in the form of variables where students must determine the value of the variable to be able to solve a problem, there are the concepts of numbers, algebra, and linear equations/inequalities. Thus, it is easier for students to understand the concept completely. Based on the above explanation, the author feels the need to conduct a development research with the title *"Development of Mathematical Literacy Instruments with Graded Response Models for Grade VII Junior High School Students*".

RESEARCH METHODS

The research used in this study is a research and development (R&D) method with a *Formative research type development model* following *Tessmer* (1993). This research consists of three stages, namely the *preliminary* stage, the self-evaluation *stage*, and the *formative evaluation* stage which goes through the expert *review process*, individual (*one to one*) and small group tests, and field tests (*field tests*). The research flow diagram can be illustrated as follows.

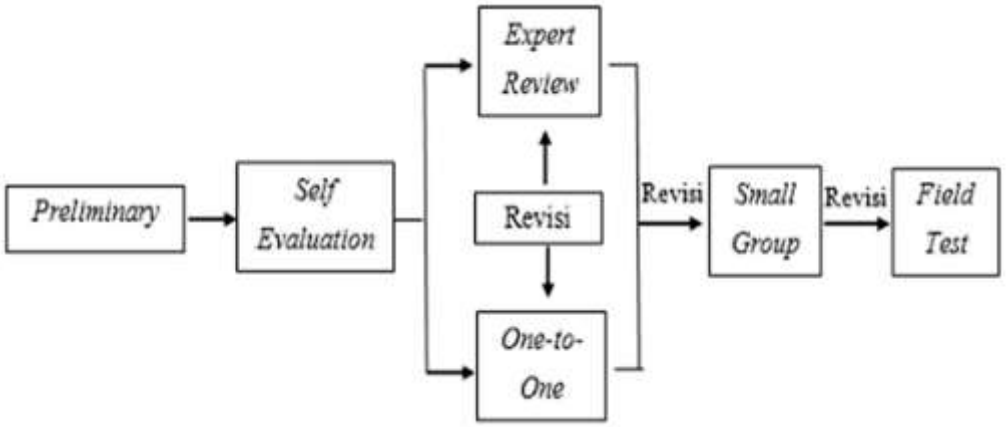


Figure 1: Tessmer Model Test Development Design (1993)
Source: Tessmer (1993)

This research was carried out to produce mathematical literacy instrument products in the form of a description test used to measure students' mathematical literacy at the junior high school level. The questions were developed with the GRM approach to measure the ability to think

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and understand concepts in depth through graded scoring. The following are the stages of the development procedure carried out in this study.

This step is also referred to as the preparation stage where at this stage it will contain various information, references, and theoretical studies that are related to mathematical literacy instruments. The relevant literature and references will be used as a strong theoretical foundation in the development of mathematical literacy instruments in the form of descriptions that are appropriate for junior high school students.

This stage contains several stages of analysis to ensure that the designed instrument has a strong theoretical and contextual basis. The stages that were passed were curriculum analysis, student analysis, material analysis, and initial design of instruments.

Next, products in the form of mathematical literacy instruments that have been made at the previous stage will be evaluated. Evaluation is carried out through *expert reviews*, individuals (*one to one*), and small groups. The design results on the *prototype* which are compiled based on the results of self-evaluation will then be given to experts (*expert review*), students (*one-to-one*), and small groups (*small groups*) in parallel. The results of these three groups will be revised.

RESULTS AND DISCUSSION

This research produced a product in the form of a mathematical literacy instrument with *a graded response model* for grade VII junior high school students. This mathematical literacy instrument was developed in the form of a description test. The process of developing this mathematical literacy instrument refers to the formative research *development procedure* by *Tessmer* (1993) which consists of four stages, namely the *preliminary stage, the* self-evaluation *stage*, and the *formative evaluation* stage. The *formative evaluation* stage will consist of three activities, namely the content validity test involving seven validators, *a one-to-one* test and a small group test conducted on grade VII students of SMP Negeri 6 Denpasar. Then in the final stage, namely the field *test* stage in four junior high schools in Denpasar City, namely junior high schools 7 Denpasar, SMP Negeri 8 Denpasar, SMP Negeri 9 Denpasar, and SMP Negeri 12 Denpasar. The question instruments used in the trial were compiled based on the learning outcomes of grade VII mathematics as well as mathematical literacy indicators in accordance with the Independent Curriculum (Phase D) which contains mathematics learning outcomes in integer and rational numbers, algebra, linear equations and inequalities of one variable, and ratios. Here are some test results below.

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1. Validity of Instrument Content

The validity of the content of the instrument was analyzed using the Lawshe method by involving seven validators consisting of three lecturers and four junior high school mathematics teachers. The results of the analysis showed that most of the items obtained a CVR value of 1, while some items obtained a value of 0.71. The overall Content Validity Index (CVI) value is 1 so that the instrument is in the category of being very suitable. This can be seen in the Table below.

Table 1. Recapitulation of the Validity of the Instrument's Content

Series	Item	CVR Value	Remarks
Series 1	1	0,71	Retained
Series 2	6	0,71	Retained
Series 3	7	0,71	Retained
Others	-	1,00	Valid

2. Internal Consistency of Question Items

The results of the internal consistency analysis showed that all question items in the mathematical literacy instrument had a product moment correlation coefficient greater than the table r-value of 0.154. In series 1, the correlation coefficient is in the range of 0.606–0.819. In series 2, a coefficient range of 0.427–0.802 was obtained, while in series 3 it was in the range of 0.514–0.830. Thus, all questions in the three series were declared consistent and suitable for use as research instruments. This can be seen in the Table below.

Table 2. Summary Table of Internal Consistency Items for Mathematical Literacy Instrument Questions

Series	Number of Items	Product Moment Coefficient Range	r Table	Remarks
Series 1	10	0,606 – 0,819	0,154	Whole grains are consistent
Series 2	10	0,427 – 0,802	0,154	Whole grains are consistent
Series 3	10	0,514 – 0,830	0,154	Whole grains are consistent

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3. Instrument Reliability

The reliability of the instrument was analyzed using the Alpha Cronbach assisted R Studio program. The results of the analysis showed a reliability coefficient of 0.894 in series 1, 0.834 in series 2, and 0.874 in series 3. These results show that the instrument has excellent reliability. This can be seen in the Table below.

Table 3. Instrument Reliability Recapitulation

Series	Alpha Cronbach	Category
Series 1	0,894	Excellent
Series 2	0,834	Excellent
Series 3	0,874	Excellent

4. Difficulty Level of Question Item

The results of the difficulty level analysis showed that most of the questions were in the medium and easy categories. In series 1, there are six questions in the medium category and four questions in the easy category. Series 2 is dominated by the easy category, while series 3 has a relatively balanced difficulty level composition between the medium and easy categories. This can be seen in the Table below.

Table 4. Difficulty Level Recapitulation

Series	Easy	Medium	Criticism
Series 1	4	6	0
Series 2	6	4	0
Series 3	3	7	0

5. Differentiating Power of Question Items

The results of the differentiating power analysis showed that all question items were in the good category. The value of differentiating power ranges from 0.401 to 0.713 so that the instrument is able to distinguish between high-ability and low-ability students effectively. This can be seen in the Table below.

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Table 5. Recapitulation of Differentiating Power

Series	DP Range	Category
Series 1	0,478 – 0,711	Good
Series 2	0,402 – 0,607	Good
Series 3	0,401 – 0,713	Good

6. Graded Response Model (GRM) Analysis

The Graded Response Model analysis showed that the instrument had good discriminating ability in measuring students' latent abilities. In item number 1 series 1, a differential power parameter of 2.36928 was obtained which showed very good discrimination ability. Meanwhile, in item number 6 series 1, a difference of 0.46029 was obtained which was in the sufficient category. This can be seen in the Table below.

Table 6. GRM Item Parameter Estimation

Item	Differentiation (a)	Interpretasi
Series 1 Number 1	2,36928	Excellent
Series 1 Number 6	0,46029	Enough

DISCUSSION

The results of the study show that the mathematical literacy instrument based on *the Graded Response Model* (GRM) developed has met the characteristics of a good instrument reviewed in terms of validity, reliability, difficulty, differentiation, and parameter estimation. The instruments developed have also gone through systematic development stages ranging from preliminary, self evaluation, expert review, one to one, small group, to field tests so that the quality of the instruments can be accounted for theoretically and empirically.

The validity of the content of the instrument in the very good category shows that the question items are in accordance with the indicators of mathematical literacy and learning outcomes of the Independent Curriculum phase D. The high values of CVR and CVI show that there is a strong agreement between validators on the quality of the developed instruments. This shows that each question item has met the aspects of material, construction, language, and contextuality.

The internal consistency of all question items above the r-value of the table shows that each item has a strong relationship with the total test score. This indicates that all question items

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are able to measure the same construct, namely mathematical literacy ability. The high internal consistency indicates that the instrument has good stability so that the measurement results can be trusted. The reliability of the instrument that is in the very good category shows that the instrument has a high level of accuracy in measuring the ability of students. The high reliability is influenced by the instrument development process which is carried out systematically and repeatedly through expert validation and revision based on test results.

Judging from the level of difficulty, most of the question items are in the medium category. This condition shows that the instrument is able to measure students' abilities optimally. Questions with a moderate level of difficulty are very effective in distinguishing students' abilities because they are not too easy or too difficult. The results of the differentiating power analysis showed that all question items were in the good category. This shows that the instrument is able to effectively distinguish students who have high and low abilities.

Analysis using the Graded Response Model showed that the instrument had good discrimination ability in measuring students' latent abilities. The GRM approach is very suitable for use in polynomial description instruments because it can provide information on students' response opportunities in each score category. Overall, the GRM-based mathematical literacy instrument developed is suitable for use as a tool for evaluating junior high school mathematics learning and can support the implementation of 21st century learning and the Independent Curriculum.

CONCLUSION

Based on the results of the development and analysis of mathematical literacy instruments that have been carried out, it can be concluded as follows; 1) Mathematical literacy instruments for grade VII junior high school students developed in the form of description questions based on daily contextual problems are designed to measure the mathematical literacy ability of grade VII junior high school students. The instrument consists of three series, namely series 1, series 2, and series 3, each of which contains 10 questions on the scope of integer and rational material, algebra, linear equations and inequalities of one variable, and ratios. 2) The mathematical literacy instrument for grade VII junior high school students developed has good quality and is suitable for use. This is shown by the results of the validity and reliability test that meet the criteria and characteristics of the question items that are at the appropriate level of difficulty and adequate differentiation. 3) The instruments developed in this study provide effective and consistent measurement information. In general, it is concluded that the higher the level of ability of

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students, the greater the opportunity for students to obtain a higher score category. 4) Based on the analysis of concurrent validity, the mathematical literacy instrument showed a significant relationship with the mathematics learning outcomes of grade VII junior high school students. Although not all question series contribute directly, the overall structure of the instrument functions quite well in representing students' mathematical literacy abilities and supporting its association with mathematics learning outcomes even though the predictive ability is in the low category.

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