JURNAL ABSIS
Jurnal Pendidikan Matematika dan Matematika
Vol. 7 No. 1, August 2024

DEVELOPMENT OF TEST INSTRUMENTS TO MEASURE MATHEMATICAL PROBLEM-SOLVING SKILLS IN QUADRILATERALS AND TRIANGLES

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ABSTRACT The aim of this research was to develop a test instrument designed to assess the mathematical problem-solving abilities of seventh-grade students in SMP/MTs, specifically in the topics of quadrilaterals and triangles. The test created is an essay-type test that meets the requirements for discriminative power, appropriate difficulty level, and both logical and empirical validity. This study utilized a development research model consisting of formative evaluation and initial stages. The formative evaluation included self-assessment, expert review, face-to-face activities, small group sessions, and field tests. The research instruments used included validation sheets, student response surveys, and the mathematical problem-solving test. Thirty-three students from class VIII.3 at SMPN 8 Pekanbaru were selected as research subjects. By validating the test instrument with three validators and testing it in small group and field test settings, the necessary data were collected. The results indicated that the average score given by the validators on the content, construction, and language aspects was 87.82%. Out of the 20 developed questions, all were logically valid, and 17 were empirically valid, with a reliability score of 0.90, categorized as very high. The difficulty levels included 13 moderately difficult questions, 2 easy questions, and 1 difficult question. The discriminative power consisted of 9 questions rated as good, 6 as fairly good, and 2 as poor. Overall, 17 of the 20 questions developed were found to have good difficulty levels, discriminative power, and both logical and empirical validity.

Keywords: mathematical problem-solving skills, test instruments, quadrilaterals, triangles.

ABSTRAK Tujuan dari penelitian ini adalah untuk mengembangkan instrumen tes yang dirancang untuk menilai kemampuan pemecahan masalah matematika siswa kelas VII SMP/MTs, khususnya pada topik segi empat dan segitiga. Tes yang dibuat berbentuk uraian dan memenuhi persyaratan daya pembeda, tingkat kesulitan yang sesuai, serta validitas logis dan empiris. Penelitian ini menggunakan model penelitian pengembangan yang terdiri dari tahap evaluasi formatif dan tahap awal. Evaluasi formatif meliputi penilaian diri, peninjauan ahli, kegiatan tatap muka, sesi kelompok kecil, dan uji lapangan. Instrumen penelitian yang digunakan meliputi lembar validasi, survei tanggapan siswa, dan tes pemecahan masalah matematis. Sebanyak tiga puluh tiga siswa dari kelas VIII.3 SMPN 8 Pekanbaru dipilih sebagai

https://doi.org/10.30606/absis.v7i1.2481

subjek penelitian. Melalui validasi instrumen tes dengan tiga validator dan pengujiannya dalam kelompok kecil serta uji lapangan, data yang diperlukan berhasil dikumpulkan. Hasil penelitian menunjukkan bahwa rata-rata skor yang diberikan oleh validator pada aspek isi, konstruksi, dan kebahasaan adalah 87,82%. Dari 20 soal yang dikembangkan, semuanya valid secara logis, dan 17 soal valid secara empiris dengan skor reliabilitas 0,90, yang dikategorikan sangat tinggi. Tingkat kesulitan terdiri dari 13 soal dengan tingkat kesulitan sedang, 2 soal mudah, dan 1 soal sulit. Daya pembeda terdiri dari 9 soal yang dinilai baik, 6 soal cukup baik, dan 2 soal kurang baik. Secara keseluruhan, 17 dari 20 soal yang dikembangkan terbukti memiliki tingkat kesulitan, daya pembeda, serta validitas logis dan empiris yang baik.

Keywords: Kemampuan Pemecahan Masalah Matematis, pemecahan matematis, instrument tes, segiempat dan segitiga.

INTRODUCTION

Assessment is a crucial component in education, serving to measure students' achievement in mastering the content they have learned (Idrus, 2019). Rohmad (2017) defines assessment as the systematic practice of collecting data or information about the outcomes of the learning process to determine whether students have changed and to what extent these changes impact their lives. Therefore, assessment becomes the final step in the learning process, aiming to evaluate how well students understand the topics taught and the learning outcomes achieved. Improving the quality of learning and the evaluation process are two ways to raise educational standards. Hence, the proper implementation of assessment processes is necessary to collect accurate data for decision-making and to enhance the effectiveness of the learning process.

Teachers require specific tools or devices to carry out assessments. According to Hamzah (2014), assessment instruments in mathematics education are measuring tools used to determine how well the mathematics learning process achieves its objectives. These instruments can be in the form of tests or non-tests, used to evaluate the attainment of the desired skills. Before using the instruments, teachers must ensure their validity to produce reliable data. According to Arikunto (2021), the validity of an instrument depends on the benchmarks used. A good instrument meets the criteria of validity, reliability, appropriate difficulty level, and adequate discriminative power.

Additionally, test instruments should reflect real-world problems. When creating instruments, teachers must consider the relevance between the test instruments and students' learning environments. However, in practice, teachers often fail to consider real-world contexts that relate to students' experiences. Based on initial interviews with mathematics teachers at SMP Negeri 8 Pekanbaru, it was found that the assessment instruments used are typically taken from textbooks without further development to reflect students' daily lives. Consequently, the assessment process becomes less engaging for students as the questions do not integrate with their real-life experiences.

Mathematical problem-solving skills are one of the essential competencies that must be developed through test instruments. Problem-solving skills are crucial for students in learning mathematics. this is because KPMM is one part of Hard Skill (Hendriana & Utari, 2017). Hard Skill is a mathematical ability that someone has related to the branch of mathematics itself (Mulyati et al., 2016). Effendi (2012) emphasizes that problem-solving skills are the foundation of mathematics education because they help students understand ideas and principles and effectively tackle mathematical problems. To solve problems, students are expected to possess strong mathematical problem-solving skills (Damayanti et al., 2022). Mathematical problem-solving skills refer to the potential that students have to address story problems, non-routine problems, and apply mathematical concepts in daily life (Andayani & Lathifah, 2019).

However, students' mastery of mathematical problem-solving skills in Indonesia remains low, as evidenced by the country's performance in TIMSS and PISA rankings, which are still far below the global average. For instance, in TIMSS 2015, Indonesian students scored an average of 397, ranking 44th out of 49 countries, well below the international average of 500. Meanwhile, the 2022 PISA results show that Indonesia ranks 70th out of 81 countries with a score of 366 in mathematics, reflecting a decline from the 2018 PISA score of 379. The questions in TIMSS and PISA are generally designed to measure mathematical problem-solving skills.

Ningsih et al (2019) found that, out of 38 students, 52.63% did not write down what was known and asked, 65.79% could not create a mathematical model, 60.53% were unable to calculate accurately, and 60.53% failed to draw the correct conclusions. (Saputra et al., 2022) identified that one of the main reasons students struggle with problem-solving questions is that they are accustomed to routine questions, making problem-solving questions unfamiliar to them. Several factors contribute to the low problem-solving skills among students, one of which is the limited ability of teachers to design test instruments specifically for problem-solving. Consequently, students lack experience in tackling problem-solving test questions. Kurniawan et al (2022) argues that the deficiency in students' problem-solving skills is due to the infrequency with which they encounter non-routine questions, which becomes a challenge when they are faced with such questions.

Based on interviews with seventh-grade mathematics instructors at SMPN 8 Pekanbaru, teachers reported that during the teaching process, they tend to use questions from textbooks without considering their relevance to students' learning environments. Wulandari (2021) found that out of 1,730 questions in the seventh-grade mathematics textbooks under the 2013 curriculum, only 33.64% were problem-solving questions, indicating that students have very few opportunities to practice problem-solving skills.

Measuring students' mathematical problem-solving skills can be effectively done through essay tests, which are the most successful type of test for assessing these

https://doi.org/10.30606/absis.v7i1.2481

skills. Arikunto (2021) states that one advantage of essay tests is that they allow students to express their ideas and thoughts comprehensively when solving problems. Kusairi & Suprananto, (2012) also noted that essay tests enable students to freely write their answers, express their thoughts, convey their opinions, and present their ideas in their own words. And descriptive questions can also help improve thought patterns because students not only solve problems but also understand the steps in solving them correctly (Kurniawan et al., 2019). Therefore, essay tests are crucial for training students to articulate their thoughts in solving mathematical problems, provided the questions meet the criteria of logical and empirical validity, as well as appropriate difficulty levels and discriminative power.

Through a literature review, the researcher identified several problems faced by students in learning about quadrilaterals and triangles. For example, Amelia, Aripin, & Hidayani (2018) found that students had difficulty identifying triangles with the same perimeter but different shapes, recalling previously learned formulas, and knowing where to start when answering questions. Regarding students' problem-solving skills, Mariana (2014) concluded that the performance of seventh-grade students in problem-solving tests on quadrilaterals and triangles showed that students struggled to generate initial ideas to answer the questions, leading to many errors. Other findings indicate that students tend to excel more in solving image-based challenges than in mathematical calculations.

Based on these conditions, the researcher developed test instruments to measure students' problem-solving skills in the topics of quadrilaterals and triangles for seventh-grade SMP/MTs students. The instruments developed are descriptive tests that are logically and empirically valid, reliable, and have appropriate difficulty levels and discriminative power.

METHODS

This study employed formative and preliminary evaluation techniques similar to those used in development studies (Prahmana, 2017). The research followed Tessmer's formative evaluation stages, which include self-evaluation, expert review, one-to-one, small group, and field test.

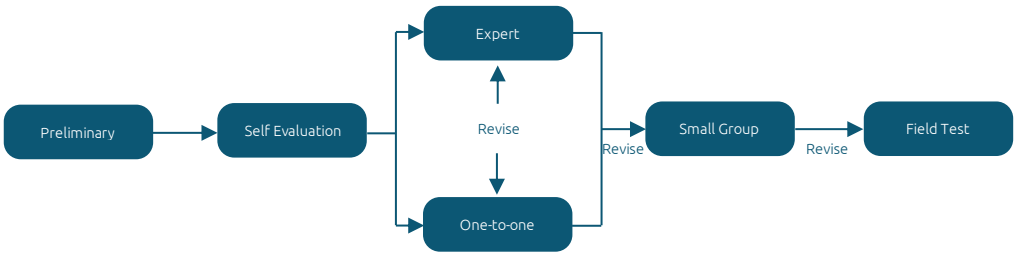

Figure 1. Stages of the Development Model

In the initial stage, analysis and design were conducted to develop a mathematical problem-solving test instrument on quadrilaterals and triangles for seventh-grade

SMP/MTs students. The analysis phase involved assessing student needs, curriculum, and learning objectives, which formed the basis for developing the test instrument. During the design phase, the research team developed the initial product, including determining the types of questions and indicators, creating a test blueprint, formulating questions, preparing answer keys and scoring guidelines, and developing validation sheets and student response questionnaires.

The formative evaluation process consisted of several key phases (Haryanto, 2020). The first phase, self-evaluation, involved the researchers reviewing the initial prototype. The second phase, expert review, involved evaluation by validators to ensure logical accuracy and gather recommendations for improvement. Validators assessed the content, construction, and language aspects using validation sheets (Febriana, 2019). Based on the feedback, the prototype was revised. In the third phase, one-to-one, three students with varying skill levels tested the prototype, providing feedback on clarity, sequence, completeness, ease of use, and product impact. This feedback was used for further revisions, resulting in the second prototype.

The fourth phase, small group, involved six seventh-grade students from SMPN 8 Pekanbaru testing the second prototype. This phase aimed to observe student performance and assess whether the previous revisions had improved the product's accuracy and effectiveness. The third prototype was then tested on 33 seventh-grade students who had studied quadrilaterals and triangles. This phase assessed the reliability, difficulty level, and discriminative power of the questions. If the test instrument met these criteria, it was considered suitable and ready for use. If it did not meet the criteria, further revisions were made until a final prototype that met all the standards was developed.

Data collection methods in this study included validation sheets, student response questionnaires, and problem-solving tests on quadrilaterals and triangles. Three validators used the validation sheets during the expert review phase to evaluate the questions on a Likert scale from 1 to 5. Student feedback on the readability of the questions was collected through questionnaires during the face-to-face, small group, and field test phases. The empirical validity of the test items, as well as their reliability, difficulty level, and discriminative power, were analyzed based on the test results (Ropii & Fahrurrozi, 2017).

Validity analysis was conducted by administering the test to 33 seventh-grade students at SMPN 8 Pekanbaru. The empirical validity of the questions was assessed using Pearson's product-moment correlation, and items with a t-value greater than the critical t-value were considered valid. The reliability of the test instrument was calculated using Cronbach's Alpha (α). The difficulty level of the test items was also analyzed to determine their appropriateness, and items that met the criteria were considered to have an appropriate level of complexity.

https://doi.org/10.30606/absis.v7i1.2481

FINDING AND DISCUSSION

In the initial stage, the researcher conducted a needs analysis, a student analysis, and a curriculum analysis. The results indicated that the design of mathematical problem-solving skills was not yet optimal, limiting teachers' ability to formulate challenging problems. This limitation reduced the opportunities for students to practice their mathematical problem-solving skills. Based on interviews with mathematics teachers at SMP Negeri 8 Pekanbaru, most of the test questions used were considered too easy and ineffective in enhancing students' problem-solving abilities. Additionally, a literature review was conducted to ensure that the developed test instruments aligned with students' perspectives. The analysis of basic competencies in triangle and quadrilateral materials aimed to identify various competency achievement indicators.

After completing the analysis, the researcher developed a mathematical problem-solving ability test instrument. The steps included creating 20 essay questions, preparing test grids, formulating questions, providing alternative answers and scoring criteria, as well as developing validation sheets and student response questionnaires. This developed instrument was referred to as Prototype I, which included questions, alternative answers, and scoring guidelines.

The initial product was then re-evaluated by academics and researchers to gather suggestions for improvements. Revisions were made to typography, question formulations, overly specific question indicators, and language errors. As a result, the 20 essay questions were divided into two test packages, each containing 10 questions, to accommodate the limited test time and ensure students could complete the test effectively. These revised test packages were then validated in an expert review stage, involving three mathematics education academics as validators. The validators assessed the content, construction, and language aspects of the test instrument to ensure its logical validity. The validation process resulted in an average validity score of 87.82%, categorizing the instrument as very valid.

Table 1. Average Scores of Validator Assessments

	Aspect		
	Content	Construction	Language
Average	4.4	4.44	4.33
Percentage (%)	88.07	88.72	86.67
Total Validation Percentage (%)		87.82	
Criteria		Very Valid	

Based on the validation results of the mathematical problem-solving ability test instrument conducted by the three validators, several improvement suggestions were provided. The first validator focused on the content component, recommending that the questions be more aligned with students' everyday life

contexts to make them more relevant and easier to understand. The second validator focused on the construction component, suggesting that the question structure be simplified to avoid ambiguity in students' interpretations. Meanwhile, the third validator highlighted the language component, proposing improvements in clearer and more consistent language use to prevent misunderstandings. These suggestions were then used as the basis for revising the test instrument to make it more valid and effective in assessing students' problem-solving abilities in triangle and quadrilateral materials.

Prototype I was subsequently tested on three students from class VIII.7 at SMP Negeri 8 Pekanbaru, each with varying ability levels. The testing was conducted on November 15, 2023, with an estimated time of 2x40 minutes for each test package. Following the test, interviews were conducted to gather feedback, which was then used to revise the questions, resulting in Prototype II. This version was tested on six students from the same class on November 21, 2023. The analysis of student responses showed that both test packages met the validity criteria, with readability considered good based on positive feedback.

The research involved analyzing the validity, difficulty level, and discrimination category of two sets of test questions designed to assess students' mathematical problem-solving skills. The analysis was conducted to ensure that each test item was both reliable and effective in measuring the intended competencies. The first table presents the results for Test Package 1, detailing the calculated validity (t calculated), difficulty level (as indicated by the difficulty index), and the discrimination category (as indicated by the discrimination index). Similarly, the second table provides corresponding results for Test Package 2. These tables offer a comprehensive overview of how each question in the respective packages performed across the three key metrics, thereby informing any necessary revisions to enhance the tests' effectiveness and fairness.

Table 2 Results for Test Package 1

No	$t_{calculated}$ (Validity Criteria)	Difficulty Index (Difficulty Level)	Discrimination Index (Discrimination Category)
1	5.99 (Valid)	0.66 (Moderate)	0.38 (Fair)
2	6.43 (Valid)	0.63 (Moderate)	0.50 (Good)
3	6.19 (Valid)	0.59 (Moderate)	0.49 (Good)
4	5.21 (Valid)	0.78 (Easy)	0.42 (Good)
5	7.03 (Valid)	0.81 (Easy)	0.46 (Good)
6	5.53 (Valid)	0.70 (Moderate)	0.35 (Fair)
7	3.02 (Valid)	0.19 (Difficult)	0.26 (Fair)
8	1.20 (Invalid)	-	-
9	5.87 (Valid)	0.46 (Moderate)	0.48 (Good)

https://doi.org/10.30606/absis.v7i1.2481

No	$t_{calculated}$ (Validity Criteria)	Difficulty Index (Difficulty Level)	Discrimination Index (Discrimination Category)
10	1.29 (Invalid)	-	-

Table 3 Results for Test Package 2

No	$t_{calculated}$ (Validity Criteria)	Difficulty Index (Difficulty Level)	Discrimination Index (Discrimination Category)
1	2.10 (Valid)	0.73 (Easy)	0.18 (Poor)
2	2.10 (Valid)	0.61 (Moderate)	0.17 (Poor)
3	2.62 (Valid)	0.41 (Moderate)	0.22 (Fair)
4	4.02 (Valid)	0.51 (Moderate)	0.47 (Good)
5	9.27 (Valid)	0.63 (Moderate)	0.55 (Good)
6	12.01 (Valid)	0.62 (Moderate)	0.58 (Good)
7	4.65 (Valid)	0.46 (Moderate)	0.57 (Good)
8	3.89 (Valid)	0.41 (Moderate)	0.28 (Fair)
9	1.50 (Invalid)	-	-
10	4.62 (Valid)	0.39 (Moderate)	0.36 (Fair)

A field test was later conducted on 33 students from class VIII.3 at SMP Negeri 8 Pekanbaru, with a test time of 3x40 minutes for each package. The analysis revealed the empirical validity, reliability, difficulty level, and discrimination of the test questions. Using Pearson's product-moment correlation and a t-test, it was determined that questions with a t-calculated value greater than the t-table value (t-table = 2.040 at a 95% significance level) were considered valid. The reliability test, based on Cronbach's Alpha, showed a coefficient of 0.90, indicating that the questions were highly reliable. The difficulty levels and discrimination indices were analyzed, confirming that the questions were appropriately challenging and effective for assessing students' problem-solving skills.

Based on the research findings, the final product is a mathematical problem-solving skills test instrument using quadrilateral and triangle materials. This instrument is reliable, logically and empirically valid, sufficiently challenging, and able to differentiate between various student skill levels.

In the preliminary analysis, it was identified that teachers faced difficulties in designing questions that effectively assess mathematical problem-solving skills. This limitation resulted in students lacking experience with such questions. To ensure the test instrument aligned with students' cognitive development, the researcher examined student characteristics through literature analysis, focusing on seventh-grade students. The curriculum analysis included an evaluation of basic

competencies related to quadrilaterals and triangles to determine relevant competency indicators.

The researcher developed 20 essay-type questions, created a test blueprint, prepared alternative solutions and scoring guidelines, and designed validation sheets and student response questionnaires. This complete product was referred to as Prototype I.

During the self-evaluation stage, additional assessments were conducted to determine validity, leading to revisions before proceeding to the expert review stage. Three mathematics education lecturers validated the 20 questions, focusing on content, construction, and language. The test instrument achieved an average validity score of 87.82%, categorized as very valid. However, some language aspects required revisions to improve clarity and comprehension. Following the expert review, revisions were made based on the validators' feedback, such as rephrasing questions to eliminate ambiguity and ensure clarity. For example, one question was revised to follow a clearer, more structured format.

The one-to-one stage involved testing Prototype I with three eighth-grade students of varying abilities. Feedback from these students led to further revisions, resulting in Prototype II, which was then tested in a small group setting with six students. The analysis of student feedback showed that while the questions were generally well-received, some were considered too long or difficult, and the time allocated was insufficient. Prototype II was revised accordingly to create Prototype III for the field test stage.

The final field test involved 33 eighth-grade students and aimed to evaluate the difficulty level, reliability, empirical validity, and discrimination of each question. The researcher encountered challenges, such as having to replace the originally planned seventh-grade students with eighth graders due to curriculum changes. However, this was resolved by ensuring that the material was still fresh in the students' minds.

Empirical validity results indicated that 17 out of 20 questions were valid. The three invalid questions were excluded from further analysis. The reliability analysis yielded a very high score of 0.90, confirming the instrument's reliability. Most questions had moderate difficulty levels, with a few being easy or challenging. The questions were generally considered good, as none were too easy or too difficult.

In terms of discrimination, most questions effectively differentiated between high- and low-ability students, though two questions were found to be less effective and were subsequently revised. The final set of 17 questions was determined to be both valid and reliable, capable of distinguishing between varying levels of student ability.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings and discussion, 17 out of the 20 questions in the two sets of tests on quadrilateral and triangle topics, developed using the research and development model that includes formative evaluation and preliminary stages (one-

https://doi.org/10.30606/absis.v7i1.2481

on-one testing, small group testing, field testing, expert review, and self-evaluation), were determined to be logically and empirically valid, reliable, of appropriate difficulty, and capable of effectively distinguishing between varying student skill levels.

To maximize the effectiveness of the developed test instrument, it is recommended that the tests be trialed in schools with good accreditation. Additionally, no more than five questions should be administered per session to ensure that students have sufficient time to complete them, thereby preserving the quality and integrity of the test instrument.

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