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Development of Test Instruments to Measure Mathematical Problem-Solving Ability in SPLDV Material

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ABSTRACT

This study aims to develop a test instrument to measure students' mathematical problem-solving ability on the topic of Two-Variable Linear Equation Systems (SPLDV) for Phase D students. The research employed a development study approach using Tessmer's formative research model, consisting of preliminary and formative evaluation stages, including self-evaluation, expert review, one-to-one, small group, and field test. The instrument was validated by experts in terms of content, construction, and language, and tested for validity, reliability, difficulty level, and discrimination power. The results showed that the developed instrument was highly valid, with a reliability coefficient of 0.95, indicating very high consistency. The items varied in difficulty levels (easy, moderate, and difficult) and demonstrated good discrimination power in distinguishing high- and low-ability students. The developed test instrument is considered feasible and effective for measuring and improving students' mathematical problem-solving abilities and can be used by teachers as a reference for assement in mathematics learning.

KEYWORDS

Mathematical Problem-Solving
Test Instrument Development Two-Variable Linear Equation System
Phase D
Tessmer Model

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1. Introduction

Mathematics is very closely related to problem solving. The skills taken by students in mathematics learning in junior high school (SMP) not only calculate and solve problems but also form the ability to solve problems both in daily life and related to mathematics itself. One of the goals of mathematics learning is solving problems which includes the ability to understand problems, design mathematical models, solve models or interpret the solutions obtained (Johar et al., 2025). This is written in the Decree of the Head of the Education Standards, Curriculum, and Assessment Agency of the Ministry of Education and Culture Number 032 of 2024, which states that one of the goals of mathematics learning is to solve problems which include the ability to understand problems, design mathematical models, solve models or interpret the solutions obtained.

One of the goals of mathematics learning according to the 2024 National Education Regulation is that students can solve problems, including problem understanding, model design, solution, and solution interpretation. Mathematical problem solving is one of the mathematics activities that is considered important by both teachers and students at all levels from elementary school to high school (Rohani, 2015; Wong & Yip, 2023). Problem-solving ability is an ability that is used to solve problems by applying various approaches, contexts and strategies, as well as reflecting on each problem-solving process used (Harahap & Surya, 2017). Problem-solving skills are a learning process that awakens students to play an active role so that they can accept and respond to questions submitted properly and can overcome difficulties in solving a problem (Prasetyo et al., 2021). Various studies have also shown that problem-solving skills are very important for students to have. The education curriculum in Indonesia emphasizes the same thing. Therefore, students' problem-solving skills are very important to be developed (Nurhayanti et al., 2020; Oh, 2025).

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However, facts in the field show that the mathematical problem-solving skills of students in Indonesia are not optimal. From the results of the study, it is shown that students' problem-solving skills, especially in solving mathematics problems in daily life, are very low (Pramuditya et al., 2022) The test conducted (Junitasari, 2021) at the junior secondary level showed that 43 students out of a total of 49 students showed low results in terms of mathematical problem-solving ability tests. They have not been able to solve the two problem-solving problems properly, and some key indicators such as understanding the problem, creating a solution planning syntax, processing the solution according to plan, and checking back are not achieved.

The low mathematical problem-solving ability of students cannot be separated from mathematics learning activities (Arofah & Noordyana, 2021). So far, mathematics learning seems to be less touching on the substance of problem solving. Students tend to memorize mathematical concepts, so students' problem-solving skills are very lacking (Damianti & Afriansyah, 2022). Students are not encouraged to find their own ideas, only teachers always play an active role in the teaching and learning process. This is supported by Narohita (Novitasari & Hestu, 2018) who revealed that mathematics learning is still dominated by teachers because teachers pursue curriculum targets to complete learning materials or teaching materials within a certain period of time. Teachers also emphasize more on students to memorize concepts, especially practical formulas that can be used by students in answering tests, without seeing the real benefits of the material taught in daily life. Thus, students will increasingly think that learning mathematics has no meaning for their lives. In fact, problems in daily life should ideally be the beginning of learning mathematics. This is because problems in daily life are the initial basis for the formation of students' knowledge (Latifah & Luritawaty, 2020).

In line with the interview conducted by the researcher with the teachers of SMP Negeri 1 Tempuling, it was found that most of the students still had difficulty in doing the tests given by the researcher because of the lack of questions that could improve students' mathematical problem-solving skills, so that there was a need for a test instrument that could improve students' mathematical problem-solving skills.

One of the government's efforts to improve students' problem-solving skills is through the implementation of the independent curriculum. This curriculum emphasizes learning that gives rise to problem-solving skills, both in the learning process and in student learning outcomes. This means that problem-solving skills are not only developed in the learning process, but must also be supported by test instruments that can improve students' mathematical problem-solving skills. This is because test instruments are an integral part of the learning process in the classroom. Therefore, the test instruments made by teachers should be able to direct students to come up with mathematical problem-solving skills (Johar et al., 2025)

However, there are still some problems that occur in the field, for example, existing test instruments focus more on the cognitive domain, besides that teachers' knowledge of test instruments is still very low, so they cannot make good quality test instruments (Wangsa et al, 2021). The quality in question is a test instrument that meets academic requirements, such as validity and reliability, so that it can be used as a tool to measure a measurement object or collect data about a variable (Suarjana, 2020). Therefore, the focus of this research is to develop a mathematical problem-solving ability test instrument as an alternative solution to help teachers realize learning that can develop students' mathematical problem-solving skills.

The Two-Variable Linear Equation System (SPLDV) is one of the materials taught in mathematics learning for the junior high school (SMP) education level. SPLDV material is one of the materials that is closely related to daily life (Maspupah & Purnama, 2020), requires strong problem-solving skills (Pesona & Yunianta, 2018), and is a prerequisite material for higher education levels (Luthfia & Zanthy, 2019). Therefore, it is important for students to have a good understanding and mastery of SPLDV capabilities (Azka & Ruli, 2022). One of the indicators of students' good understanding of SPLDV material is the difficulty of students in understanding the material and solving SPLDV questions. But in reality, what happened was the opposite. Students still have difficulties in understanding SPLDV material (Hanipa & Sari, 2019), solving SPLDV problems where the indicators explain ideas, situations and mathematical relationships, orally and in writing using real objects, pictures, graphs and expressions, SPLDV is included in the moderate criteria with a percentage of 33.33%; students' ability to express everyday events in language or mathematical symbols or compile mathematical models of an event is included in the low criteria with a percentage of 18.18%, the ability of students to explain and make mathematical questions studied in the low criteria with a percentage of 7.58% and the ability of students to formulate arguments, formulate definitions and generalizations in the low criteria with a percentage of 7.58% (Purwandari et al.,

2018), as well as representing the SPLDV problem into an appropriate mathematical form (Anggraeni et al., 2018).

Based on the importance of mathematical problem-solving skills for students in mathematics learning, research is needed to develop a test instrument for mathematical problem-solving ability of SPLDV phase D materials.

Mathematical problem-solving ability test instruments must be proven to be valid to prove their validity in measuring what should be measured (Budiastuti & Bandur, 2018). The validity of the questions developed is carried out through internal validity and external validity. Internal validity is carried out to assess whether the questions meet the applicable requirements based on expert assessments (Nuryadi & Khuzaini, 2016). Meanwhile, external validity is carried out to measure the accuracy and precision of the results of measuring question items in measuring what is to be measured from the developed questions. The reliability of the questions needs to be known in order to determine the consistency of the questions developed in carrying out measurements on the same measurement subject at different times (Mansyur et al., 2019). Questions need to have good differentiating power in order to distinguish high-ability students from low-ability students (Hamzah, 2014). Good test questions are questions with a level of difficulty that is not too easy or too difficult for students to solve (Nuryadi & Khuzaini, 2016).

After obtaining the values of validity, reliability, differentiation, and difficulty of the developed mathematical problem-solving skills, valid, reliable, and trustworthy questions can be produced. The resulting mathematical problem-solving skills can be used by students in training and developing their mathematical problem-solving skills. The questions developed aim to reference mathematical problem-solving test questions used by teachers as formative test questions, daily tests, mid-semester exams, and end-of-semester exams and facilitate students in practicing their mathematical problem-solving skills by practicing solving developed mathematical problem-solving problems.

2. Method

The development model used in this study is a development research type of development studies. This type of development studies aims to develop principles, designs, and products for practical benefit in the field. This is in accordance with the purpose of this study, which is to produce a mathematical problem-solving ability test instrument to be used in training and developing students' mathematical problem-solving skills. The stages carried out in this study consist of two stages, namely preliminary and formative evaluation. The formative evaluation stages include self evaluation, expert review, one-to-one, small group, and field test (Tessmer in Dewi & Syofiana, 2020). The flow of stages of this research model can be seen Figure 1.

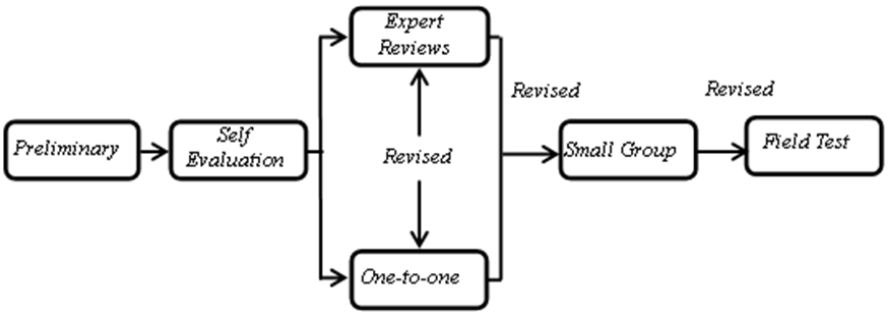


Fig. 1. Research Model Flow

The instruments used in collecting data in this study consist of: There are two data in this study, namely qualitative and quantitative data. The data collection tools from this study were (1) interviews with several teachers of SMP Negeri 1 Tempuling and MTs Sungai Salak related to the questions used; (2) Distribution of questionnaires at the expert review stage, one-on-one, and small groups; (3) Validity, reliability, difficulty, and differentiating power; (4) Documentation. The assessment instrument developed was used to measure students' KPMM on SPLDV content. The criteria for scoring KPMM indicators in this study refer to the scoring guidelines contained in Table 1.

Table 1. Scoring Guidelines

Indicators	Reaction to the Question	Score
Understanding the Problem	Students don't write down what they know and what they ask on the test	0
	Students write down what they know but don't mention what was asked on the test or vice versa	1
	Students write down what they know and what they ask on the test but are not precise	2
	Students write down what they know and what is asked on the test precisely	3
Plan for Troubleshooting	Students don't write and don't plan at all	0
	The student plans a strategy but does not fit the problem at all and is not appropriate	1
	Students plan strategies but only some are appropriate and less appropriate	2
	Students plan strategies appropriately but inappropriately	3
	Students plan strategies appropriately and appropriately	4
Troubleshooting	Students do not implement strategies at all	0
	The student implements the strategy but does not follow the plan, is incomplete and the calculation is wrong	1
	The students carry out the strategy but some of the appropriate ones are incomplete, and the calculations are correct	2
	Students carry out strategies appropriately, incompletely, and the calculations are correct	3
	Students carry out strategies appropriately, completely and correctly	4
Reinterpret the answers obtained	Students do not write conclusions	0
	Students draw conclusions but are wrong	1
	Students make conclusions correctly	2

(Purnamasari & Setiawan, 2019)

3. Results and Discussion

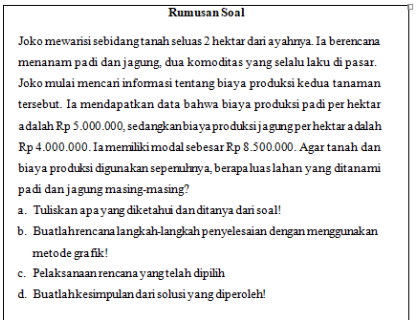
The researcher used a formative research type development model by Tessmer. The results of the research for each stage carried out by the researcher are described into several parts.

3.1. Preliminary Stage

The researcher conducted the stages of selecting the place and subject of the trial and selected class XI of high school/MA with heterogeneous academic abilities in Pekanbaru and the school has never used KPPM, namely SMPN 1 Tempuling and MTs Nurul Hidayah. Then the researcher carried out analysis activities carried out through literature studies and interviews with mathematics teachers in the school environment of SMPN 1 Tempuling and MTs Nurul Hidayah. In the needs analysis, the results were obtained that if students were given problems of daily events in different forms, but students were unable to do them, the test instruments currently used by teachers were not able to measure the level of problem solving of students, most teachers did not know the students' KPMM and there were minimal references to mathematical problem-solving skills tests available. In the analysis of students, it was found that students with low abilities could not work on story problems and had low grades or in other words, students had not completed working on story problems. In the curriculum analysis, it is carried out to determine the suitability of the objectives needed in developing mathematical problem-solving ability test questions to be in accordance with the demands of the independent curriculum. In the curriculum analysis, a study of learning outcomes related to SPLDV material in the independent curriculum was also carried out. The learning outcomes in the SPLDV Phase D material are as follows: At the end of phase D, students can use "variables" to solve equations and linear inequalities of one variable. They can solve a system of linear equations of two variables through several ways for problem solving.

In the preliminary stage after the analysis is carried out, the next stage is to design research products according to the results of the analysis obtained. The activities are in the form of 1) Determine the type of questions and indicators of mathematical problem-solving ability used as a reference, 2) Formulate a grid of mathematical problem-solving ability test questions, 3) Formulate mathematical problem-solving ability test questions, 4) Develop alternative solutions and scoring guidelines, 5) Compile assessment

rubrics, and 6) Compile validation sheets and student response questionnaires. An example of a test question can be seen in figure 2



Rumusan Soal

Joko mewarisi sebidang tanah seluas 2 hektar dari ayahnya. Ia berencana menanam padi dan jagung, dua komoditas yang selalu laku di pasar. Joko mulai mencari informasi tentang biaya produksi kedua tanaman tersebut. Ia mendapatkan data bahwa biaya produksi padi per hektar adalah Rp 5.000.000, sedangkan biaya produksi jagung per hektar adalah Rp 4.000.000. Ia memiliki modal sebesar Rp 8.500.000. Agar tanah dan biaya produksi digunakan sepenuhnya, berapa luas lahan yang ditanami padi dan jagung masing-masing?

a. Tuliskan apa yang diketahui dan ditanya dari soal!
b. Buatlah rencana langkah-langkah penyelesaian dengan menggunakan metode grafik!
c. Pelaksanaan rencana yang telah dipilih
d. Buatlah kesimpulan dari solusi yang diperoleh!

Fig. 2. Sample Questions

3.2. Formative Evaluation Stage

The formative evaluation stage in this study includes:

3.2.1. Self Evaluation

At the self-evaluation stage, the initial product in the form of a mathematical problem-solving ability test question grid and a question card containing test questions, question indicators, indicators of mathematical problem-solving ability, material coverage, and alternative solutions along with scoring guidelines along with the instruments used in the research were reassessed by the researcher assisted by the supervisor. The results of the assessment with the supervisor produced a mathematical problem-solving ability test instrument consisting of 18 which included the submeter of solving the SPLDV with graph, substitution, elimination and mixture methods. The initial product is then approved for expert validation and a one-to-one stage. This initial product was hereinafter referred to as prototype I.

3.2.2. Expert Review

Internal validation of prototype I by three experts at the expert reviews stage was carried out by providing validation sheets, validation sheet rubrics, mathematical problem-solving ability test instrument grids, mathematical problem-solving ability questions, mathematical problem-solving ability test cards, alternative solutions and scoring assessment guidelines to be assessed from material, construction, and language aspects. The results of the assessment by the validator produce qualitative data and quantitative data. The qualitative data obtained was in the form of suggestions for improvement and the results of the analysis carried out by the validator both on the question indicator component and the question item.

Quantitative data was obtained from the calculation of the average value of the validation assessment sheet which includes three aspects of iteria consisting of material aspects, construction aspects, and language aspects as follows:

Table 2. Validation Results of Each Aspect

	Aspects		
	Material	***Construction***	***Language***
Total Score	40,97	35,79	36,07
Average	4,55	3,97	4,01
Percentage	91	79,5	80,3
Category	Highly Valid	Valid	Highly Valid
Total Validity (%)	83.53 (Highly Valid)		

The average score of the validation of the entire question item based on the material aspect was 91%, which was in the value range of 80% < Va ≤100% of the KPMM test instruments developed were in the category of very valid, while in the validity of the construct, the average score of the validation of the entire question item based on the construct aspect was 79.5%, in the range of 60%< Va ≤80% of the test instruments developed fall into the valid category. Then in the language aspect, 80.3% was obtained in the range of 80% < Va ≤100% of the KPMM test instruments developed were included in the very valid category.

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Table 5 shows that overall the KPMM test instrument obtained an average percentage of 83.53% which is in the range of 80% < Va < 100% can be said to be a valid instrument based on the results of the validator's assessment on the aspects of the material, construct and also the language so that a product referred to as prototype I was produced.

3.2.3. One-to-one

The next stage is one-to-one. A total of 3 students of grade IX of SMP Negeri 1 Tempuling with different abilities of students to work on problems so as to obtain suggestions and comments from students regarding the readability of the developed problem-solving questions which were then analyzed and revised or improved activities were carried out so that prototype II was produced.

3.2.4. Small Group Stage

The stages carried out are small groups. A total of 6 students in the SMPN 1 Tempuling and 6 MTs Sungai Salak Pekanbaru classes worked on based problem solving problems and were then asked for comments and suggestions on the problem solving questions through the response questionnaire that had been provided so that the students' response scores to the test instruments as well as suggestions and comments were obtained for the next score to be analyzed and revised so that the revised product was obtained which was referred to as prototype III.

The processing of student response questionnaire data at the small group stage and obtained an average percentage of all statements was 86.19%. Based on the student response score criteria in table 3.2, the score percentage is in the range of 80<V_p≤100 so that it meets the criteria very well or obtains positive feedback so that the mathematical problem-solving ability test questions are considered very good in terms of readability. Suggestions and comments from 12 students at the small group stage were used as a basis for revising prototype II so as to produce prototype III that is ready to be tested on research trial subjects at the field test stage

3.2.5. Field Test Stage

The results of the revision of prototype II, which is prototype III, were tested on the subjects of the research trial, namely students of class IX.1 of SMP Negeri 1 Tempuling consisting of 30 students. The processing of student response questionnaire data and obtained the average percentage of all statements was 83.81%. Based on the student response score criteria, the percentage of the score is in the range of 80<Vp≤100 (Arifin, 2017) which meets the criteria very well, so that the final mathematical problem-solving ability test instrument is obtained. The results of students' answers to the mathematical problem-solving ability test instrument were analyzed and the validity of the question items, reliability, level of difficulty and differentiating power were determined.

The validity test of the question item was tested using the Pearson product moment formula to obtain the correlation coefficient value for each question item. The value of each question item is compared to the table at a significance level of 5%. The question item is said to be valid if $t_{counts} > t_{table}$ and invalid if $t_{counts} \leq t_{table}$ (Azwar, 2019). The results of the validity test of the test instrument questions with $t_{table} = t\alpha$ (16-2) = 2.05. The validity value of the question item is calculated using the Pearson/product moment formula. The results of the study showed that 16 questions were considered valid. Validity testing was also carried out using SPSS software version 26.

The reliability test was carried out using Cronbach's Alpha formula. The reliability test includes 16 valid questions. Based on the results of data processing using SPSS version 26, the reliability test value of 16 questions to measure KPMM is 0.95. Based on the reliability criteria according to Sa'adah et al (2019), the reliability test values in the range of 0.80–1.00 meet excellent standards. A tool that has high reliability shows a strong consistency in producing evaluation results and can be used to display the true characteristics or state of the object being tested.

The difficulty level test of the question item is used to determine the level of difficulty of the developed question. The difficulty level in the range of 0-0.30 is included in the difficult category, the difficulty level in the range of 0.30-0.70 is included in the medium category, and the difficulty level in the range of 0.70-1.00 is included in the easy category. The questions developed contain 5 questions in the easy category, 8 questions in the medium category, and 3 questions in the difficult category, so that the questions obtained to measure KPMM for phase D students in the SPLDV content are valid, reliable and have a good level of difficulty. Based on the results of the difficulty level test, it was found that there were 3 easy questions, 11 medium questions, and 2 difficult questions. According to Bagiyono (2017), a good question is a question that varies in difficulty, namely not too difficult and not too easy.

Differentiating power analysis was carried out to find out the extent to which questions can distinguish high-performing and low-performing students. The results of the differentiation analysis showed that 3 questions made to assess KPMM were in the range of 0.20-0.40 with the medium category, 12 questions were in the range of 0.40-0.70 with the good category, and 1 question was in the range of 0.00-0.20 with the bad category. This shows that the 16 questions developed were accepted. Thus, it can be concluded that the questions to measure the KPMM of phase D students in the SPLDV content have the ability to distinguish high-ability students from low-ability students (Fatimah & Alfath, 2019). This is also in accordance with the research by Mulbar et al. (2017), which states that test instruments that are valid and reliable can be used to determine students' mathematical problem-solving abilities. In addition to improving problem-solving skills, the KPPM test instrument can also enhance students' self-confidence and cognition (Hendriana et al., 2018; Mulbar et al., 2017)

The advantage in this study is that the question test instrument is valid and reliable. The test instrument is also able to measure the level of KPMM of students and can find out the response of students' answers, so that teachers can choose the right strategy during future learning.

4. Conclusion

Based on the results of the research and discussion, it can be concluded that the test instrument for the mathematical problem-solving ability of SPLDV content in grade IX SMP/MTs Phase D has met the internally valid criteria, is externally valid, has a high reliability value, and has a good level of difficulty and differentiation by using a development type development research model consisting of the preliminary and formative evaluation stages by Tessmer.

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