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Indicators and Essay Problem Grids on Three-Dimensional Material: Development of Instruments for Measuring High School Students' Mathematical Problem-Solving Ability

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Abstrak:
Salah satu komponen penting dalam sistem pendidikan untuk mengukur keberhasilan dan kinerja proses pembelajaran adalah kegiatan penilaian. Pentingnya penilaian dalam proses pembelajaran dapat dijadikan sebagai tolok ukur untuk peningkatan mutu pendidikan. Tujuan penelitian ini adalah mengembangkan alat penilaian pembelajaran matematika untuk mengukur kemampuan pemecahan masalah matematika siswa SMA. Jenis pengembangan yang digunakan terkait dengan model yang dikembangkan oleh Thiagaran. Populasi penelitian terdiri dari lima sekolah umum di kota Pasuruan. Sampel penelitian ini adalah siswa kelas XII SMA/SMK YALC Pasuruan. Teknik Pengumpulan Data menggunakan alat tes uraian untuk menyelesaikan sepuluh soal matematika tentang materi tiga dimensi. Analisis data menggunakan validitas, reliabilitas, kekuatan, dan kesukaran. Hasil penelitian ini menunjukkan bahwa instrumen tes esai sosial mengukur kemampuan pemecahan masalah matematis siswa SMA 9 item soal valid dan reliabel dan 1 soal dihapus (tidak valid). Berdasarkan hasil penelitian ini, kita dapat menyimpulkan apa yang dikembangkan dengan baik dan praktis untuk digunakan.

Kata Kunci : *Kemampuan pemecahan masalah matematis; Dimensi Tiga; Instrumen Soal; Esai*

Abstract:
One important component in the education system to measure the success and performance of the learning process is assessment activities. The importance of assessment in the learning process can be used as a benchmark for improving the quality of education. The purpose of this study was to develop a mathematics learning assessment tool to measure high school students' math problem solving abilities. The type of development used is related to the model developed by Thiagaran. The study population consists of five public schools in the city of Pasuruan. The sample of this research was class XII SMA/SMK YALC Pasuruan. The data collection technique uses a description test to solve ten math problems about three-dimensional matter. Data analysis uses validity, reliability, strength, and difficulty. The results of this study indicate that the social essay test instrument measures the mathematical problem-solving abilities of high school students. 9 items are valid and reliable and 1 item is deleted (invalid). Based on the results of this research, we can conclude what is well developed and practical to use.

Keywords : *Mathematical problem-solving ability; Three Dimensions; Question Instrument; Essay.*

Introduction

One of the natural processes of human development is education. Education in the 21st century is an age of knowledge, and the tremendous growth of knowledge is accelerating (Inganah et al., 2023; Kim et al., 2019; ND Safitri et al., 2023). Education is becoming increasingly important to enable students to learn competently and innovatively

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(Anjarwati et al., 2023; Hasanah et al., 2022; Setiawan et al., 2019). The main activity in education is learning, and through learning activities a process of positive change occurs in both knowledge and behavior. One important component in the education system to measure the success and performance of the learning process is assessment activities (Haryanti & Saputra, 2019). The importance of assessment in the learning process can be a benchmark for improving the quality of education (Darmayanti, et al., 2022; Humaidi et al., 2022; Vidyastuti et al., 2022). This allows the assessor to interpret student growth and progress in relation to the goals and conditions set out in the curriculum. Assessment plays an important role for students and teachers (Zamanzadeh et al., 2015). This is because the assessment allows students to see the degree of competence in dealing with problems presented by the teacher, and for the teacher it serves as feedback to determine benchmarks for their abilities and success in dealing with the learning process.

The first part of the learning process is how students learn. The Islamic perspective is also important considering that humans are weak, forgetful creatures with limited recovery. To know the strength of the faith of His servants, Allah SWT says in QS Al-Ankabut/29: 2-3 saying:

> *"Do you think they will say 'we believe' without being checked? (3) We have indeed tested those before them."*

Therefore, it is important to have an assessment in an effective learning. The effectiveness of learning programs must be measurable in order to see students' understanding of facts, phenomena, principles, concepts, laws, theorems and their applications (Alshammari et al., 2022; Radeswandri et al., 2021; Sah et al., 2023). For this reason, a valid and reliable assessment is needed to measure the results and impact of learning. Assessment has three main functions, namely: (1) knowing the knowledge gaps possessed by students before learning begins; (2) knowing the overall student learning outcomes; (3) Knowing the strengths and weaknesses of students. The test is a systematic instrument consisting of a set of questions to measure certain behaviors for students with certain categories (Camacho, 2018; Sekaryanti et al., 2022).

Furthermore, the results of the evaluation activities in the form of measurement and evaluation above show the success of the implemented educational program (Darmayanti, Syaifuddin, et al., 2022; Rizki et al., 2022; Wulandari et al., 2022). The tool that is commonly used by teachers to measure learning outcomes by measuring the ability or possibility of student learning outcomes is a test instrument (Fauza et al., 2022; Leton et al., 2019). The test tool is a measuring tool that is used as a collector of information that contains questions or tasks that must be answered or done to measure individual or group performance. The test kit is a comprehensive assessment tool for obtaining data and information through questions and exercises (Asadchih & Dybska, 2020; Hardianti et al., 2021; ND Safitri et al., 2023). One form of tester is a subjective test, which is called an essay test.

Essay test is also called a diagnostic test. Diagnostic tests are tests that are run to make an accurate determination (Febriyanti et al., 2021). Types of problems faced by students in certain lessons. Knowing the difficulties students face helps us go further in providing the right treatment. Diagnostic tests must also find answers to the questions presented. Diagnostic assessment helps find problems faced or bothering students (Fauza et al., 2022; Fernández et al., 2021; Rahmah et al., 2022). In other words, there are many problems faced by students, and the written test asks various types of problems and seeks solutions from the diagnostic results. The purpose of a diagnostic assessment is to resolve difficulties or overcome obstacles faced by students in following a field of study or study program as a whole. Besides that, with the existence of a diagnostic test, students are required to answer the test according to their level of knowledge. Subjective tests are usually

given in the form of essays (descriptions) (Darmayanti et al., 2023; Hui et al., 2020). Students respond by recalling lessons, discussing and explaining words. In written exams, students are asked to provide explanations, interpretations, and identification in the form of questions that can show their understanding of the subject matter. Because the test instrument used in teaching is student learning outcomes, the teacher needs to ensure that the test meets the test requirements. It should be noted that a test kit can be said to be a good test if it meets the requirements of validity and reliability (Zaleha et al., 2017). Most importantly, the test kits determine the competency level and potential of students, diagnose learning disabilities in students, allow teachers to know their learning outcomes, and allow students to know their learning outcomes.

One of the assessment activities that uses tests to measure student learning outcomes and achieve the goals of learning mathematics is the ability to solve mathematical problems (Ahdhianto, Marsigit, Haryanto, & Nurfauzi, 2020; Sugianto et al., 2022). Therefore, one of the skills students must have is the ability to solve mathematical problems. Mathematical problem-solving ability, is an approach when analyzing problems to assist students in making it easy to be able to make changes to problems found in life. Basically, the problems of human life are related to the abstract form of mathematics. When math problems can be solved, students can have useful experiences in life (Darmayanti, Sugianto, et al., 2022; Güner & Erbay, 2021). Problem solving strategies used when learning mathematics can influence students' abilities (Björn et al., 2019). In this case, the most important factor during the learning process is the ability to solve problems in order to make students have a demand to be able to better understand, design and provide completion of mathematical patterns. (Brookman-Byrne et al., 2019). (Rahmawati et al., 2017), expressed his opinion where it was said that problem solving was a step towards accepting challenges in providing answers in solving mathematics in the form of contextual questions.

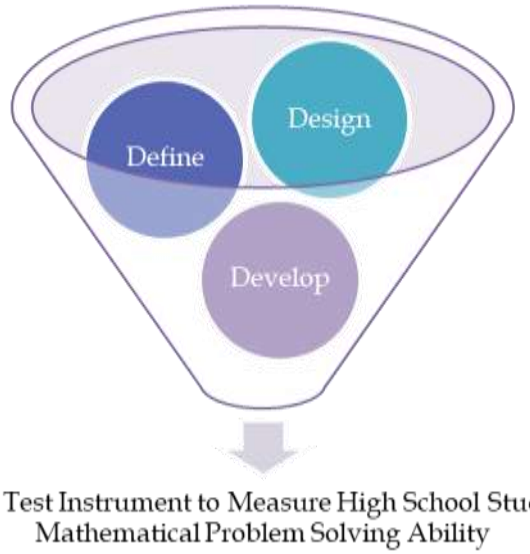
The characteristics contained in problem solving are that problems require thinking, which can provide a challenge for students in making predictions and obtaining appropriate and appropriate answers and evidence (Ahdhianto, Marsigit, Haryanto, & Santi, 2020). Solving students' mathematical problems has a meaning in the form of the ability of students to be able to form an understanding of problems, planning strategies related to solutions, implementing resolution strategies and checking related to solving problems. In this case, later the mathematical solution will provide a more precise representation (Sterner et al., 2020). The teacher has a role to control learning so that it can improve the ability of students when solving the problems they face (Naufal, 2021).

From the several opinions about problem-solving abilities above, this study aims to produce valid and reliable tests of three-dimensional mathematical problem-solving abilities in subjects, as well as to determine the distinguishing power and level of difficulty of the questions. This study aims to contribute to the field of mathematics, especially geometry. The ability to solve mathematical problems in this essay is the ability to guide the mind to make statements in solving problems to arrive at a conclusion. Based on Polya's learning proposition, there are four procedures applied to solve problems, namely (a) understanding problems, (b) preparing problem solutions, (c) solving planned problems, and (d) re-checking related problems that have been resolved (Meryansumayeka et al., 2021).

Research Methods

This research was conducted in January 2022. The type of research used in this research is the Research and Development (R&D) method according to Thiagarajan. The R&D research method is a development research method used to manufacture products. The procedure for developing this model is known as *the four-D stage,* but this research only

takes three steps: (1) research and information gathering (define), (2) planning and initial product development (design), (3) initial field trials, major product revisions, key field trials, and operational product revisions (develop). The flow of these stages is presented in Figure 1.



Gambar 1. Alur tahapan Pengembangan Instrumen Kemampuan Pemecahan Masalah Matematis dengan Teori model Thiagaran

The development of a mathematical problem-solving test instrument requires qualitative and quantitative data. The design used is the (Leung, 2015) plot exploration design described in Figure 2.

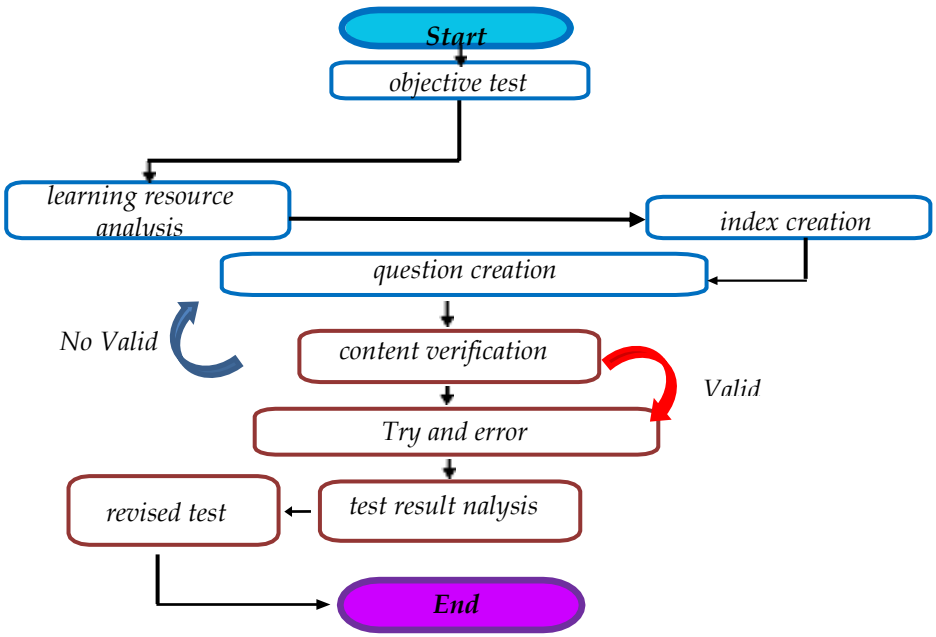


Figure 2. The procedure for making a mathematical problem

According to the flow or sequence in development which refers to the theory of Thiagarajan, the first step is *define*. In this first stage is a preliminary study, which is carried out in the form of a literature search (literature *study* by finding and reading articles in international and national journals, referring to books on problem solving skills and

materials on three dimensions). This is in accordance with the works (Srirahayu & Arty, 2018). The second step is *design,* the activities carried out at this stage consist of device design (curriculum analysis, student analysis, material analysis). The design of the instrument is based on a three-dimensional material grid and an index of mathematical problem-solving ability. After the design is created, the design is verified. This verification stage is included in the third stage, namely *develop,* where this step consists of face verification and content verification (Anwar et al., 2021). In considering face validity, the consideration needed is the clarity of the test questions relating to language, expression, and the accuracy of images, symbols, or illustrations. To validate the contents of the requested considerations regarding the suitability of the questions with the measurands, the suitability of the mathematical problem-solving aspects of the questions with the criteria, and the suitability with the differential equation material. Validation was carried out by two mathematics lecturers, two teachers, and two mathematics education practitioners. The draft is then revised based on suggestions or input from the validator. After revision, the tool was tested on students to measure the effectiveness of the questions, test reliability, discriminating power, and difficulty.

For visual and content validity, the validator gives a score of 1 if the test item is considered valid and a score of 0 (zero) if the test item is considered invalid. assigned. We then analyzed the results of the validator using the Cochrane's Her Q test with a significance level of $\alpha = 5\%$. If the significance of the calculation is greater than $\alpha = 5\%$, the test items are considered valid or interpreted as a weighing tool that provides the same assessment. The tool which was declared valid by several validators was then tested. The test subjects in this study used a purposive sampling technique, namely a non-probability sample using a sampling technique with certain considerations to identify the subject or sample. The research subjects were 25 students of class XII.

Researchers analyzed test results to measure the efficacy, reliability, discriminatory power, and difficulty of each item. The effectiveness of an item is determined by determining the correlation coefficient between the item score and the total score. The correlation coefficient is determined by the Pearson product-moment correlation equation. Test reliability was determined using the Cronbach's alpha formula. The test confidence coefficient, selectivity and difficulty, as well as the interpretation of the correlation coefficient follow the categories (Leung, 2015).

Results and Discussion

The development of the developed mathematical problem-solving ability instrument refers to the sequence of stages from the theory of the Thiagaran model. Detailed steps in developing the instrument are described as follows.

1. Define

At this stage, the first step is a preliminary study. It starts with collecting references to solving mathematical problem-solving tests. So, based on this, the students ' mathematical problem-solving abilities in this study are guided by the indicators listed in table 1.

Table 1. Indicator of Mathematical Solving Process

Mathematical Solving Process	Mathematical Solving Indicator
Understanding the problem	Students must be able to interpret the questions they are studying with the belief that they have

	been able to interpret the questions correctly.
Compile a list of problem-solving solutions	Students can develop strategies to overcome difficulties based on what they already know or have been asked about the problems they face in the first stage, namely understanding a problem.
Make a plan on how to solve the problem	Students start working on math problems according to the solving strategy that has been prepared before.
Review the solutions that have been implemented	Students review their answers, to ensure that the solutions given are valid and in accordance with the problem-solving process.

2. Define

The second stage is product planning. This activity aims to design an accurate troubleshooting tool steps the instrument (test kit) developed consists of test indicators, questions and evaluation tables. The four steps taken are curriculum analysis, material analysis, student analysis, and problem design.

a) Curriculum Analysis, the goal is to identify the issues involved in developing math problem solving tests. The curriculum analyzed was the 2013 curriculum used at the SMA Yayasan Assyfa Learning Center (YALC) Pasuruan, where the research was conducted. Another activity is Learning Analysis which applies face-to-face learning. Next, the student analysis, namely class XII students in the first semester, the researcher will do for first year students to learn about three dimensions. Each class consists of 35 students. However, researchers with certain considerations only chose 25 students (limited trial). Based on the results of unstructured interviews with students that solving mathematical problems, students have never been explored adequately because semester 1 students are new students transitioning from class XI.
b) Material Analysis, is an activity to identify the main concepts that will be used in designing students' mathematical problem-solving tests. Based on the curriculum analysis activities, it is known that the material to be used in research is based on the 2013 curriculum in odd semesters. Then selected on the material "Three Dimensions" basic skills 3.1 and 4.1, specifically "Describing spatial distances (between points, points to lines and points to planes)" and "determining distances in space (between points, points to lines and points to planes). An index is created for each question based on the selected material.

3. Develop

The second stage is product development. From the results of the research, six device designs were obtained that approximately described mathematical problem-solving abilities and assessment instructions. The design of the questions is then validated by the validator. The validation carried out consisted of face validation and content validation. From the issues provided through the validator, editorial adjustments have been made. The consequences of the problems provided through the validator are then analyzed using the *Q-Cochran examination*. Evaluation consequences for face validation and content material validation are presented in table two.

Table 2. Results of the Q-Qochran test using SPSS 16

Statistics	Validation

	Fill	Advance
N	6	6
Cochran's Q	3,000 [a]	5,000a –
df	7	7
Asym. Sig	.801	.417

a. one is treated as a success

From table two it can be seen that the test score results for content validation on the *Asym.sig statistic* show a value of 0.801. The value of 0.801 on the Q-Qochran test is greater than α = 0.05. As a result, based on these results it can be said that each validator pays uniform or equal attention to the content validity of the mathematical problem-solving ability instrument. Furthermore, in table 2, the results of the test scores for face validation on the *Asym.sig statistic* show a value of 0.417. The value of 0.417 on the Q-Qochran test is greater than α = 0.05. As a result, based on these results it can be said that each validator gives uniform or equal attention to the face validity of the mathematical problem-solving ability instrument (Padulo et al., 2020). So, based on the overall results it can be concluded that the instrument for students' mathematical problem-solving abilities in three-dimensional material can be said to be valid in terms of advance material and content material.

The next step is to try the tool on many students who have attended three-dimensional material. The number of students examined became 25 people. Student solution sheets are corrected and ranked according to the scoring instructions that have been prepared. Assessment instructions are presented in Table 3.

Table 3. Instructions for scoring the Mathematical problem-solving ability test instrument

Aspect	Indicator	Sub indicators	Score
Mathematical Problem Solving	Able to identify elements	Students can identify problems, understand problems seriously, and can find out what is known and asked about problems with correct final answers	4
		Students can identify problems, understand problems seriously, and can find out what is known and asked about problems but the final answer is wrong	3
		Does not understand part of the problem but mentions some of what is known and states what is being asked of the problem.	2
		Does not understand part of the problem but mentions what is known and does not mention what is being asked of the problem.	1
		Students do not answer	0
	Able to do the formulation of mathematical problems	Students can plan problem solving with the final correct answer	4
		Students can plan problem solving with wrong final answers	3
		Students can plan a solution but only part of it is correct.	2
		Students can plan problems but not correct (not	1

	according to plan).	
	Students do not answer	0
Able to compile mathematical models and able to implement problem solving strategies	Students can solve problems according to plan, do the work correctly and the final answer is correct	4
	Students can solve problems according to plan, do the work correctly and the final answer is wrong	3
	Students can solve some of the problems	2
	Students in solving problems are not in accordance with the plan.	1
	Students do not work	0
Able to draw conclusions and interpret the results of problem solving	Students can draw conclusions from the answers obtained and recheck the answers with the correct final answer	4
	Students can draw conclusions from the answers obtained and check back the answers with the wrong final answer	3
	Learners can conclude the problem but not quite right	2
	Students cannot conclude the problem	1
	Students do not work	0

Description: Value $= \frac{Jumlah\ skor\ yang\ diperoleh}{jumlah\ skor\ maksimal}\ x\ 100\%$

Student assessment notes were then analyzed to see the validity of each item. In addition, it is also used to see reliability, discriminating power and index of difficulty in each item. The validity of each item is done by correlating the rating of each object with the overall rating. The results of calculating the correlation coefficient for each object are presented in Table 4.

Table 4. Results of the Q-Qochran test using SPSS 16

item th	Results Correlation coefficient score	Category
1	0.512	Enough
2	0.443	Enough
3	0.753	Tall
4	0.538	Enough
5	0.720	Tall
6	0.439	Enough
7	0.710	Tall
8	0.433	Enough
9	0.415	Enough
10	0.732	Tall

Based on the results of calculating the correlation coefficient presented in Table 4, it can be said that each question developed can be used to measure students' mathematical problem-solving abilities in three-dimensional material. After the questions can be said to be used, the next step is to determine the reliability of the test.

To determine the reliability coefficient of the examination, the Cronbach Alpha formula is used. Scores from student test results when finished working on questions related to the ability to solve mathematical problems that will be measured. Furthermore, the results of calculating the reliability coefficient are presented in Table 5.

Table 5. Cronbach Alpha test results Using SPSS 16 to measure the level of the reliability coefficient

Cronbach's Alpha	*Cronbach's Alpha Based on Standardized Items*	*N of Items*
0837	1,000	10

Table 6. Cronbach Alpha test results Using SPSS 16 to determine deleted items

item th	*Scale Mean if Item Deleted*	*Scale Variance if item Deleted*	*Correted Item-total Correlation*	*Squared Multiple Correlation*	*Cronbach's Alpha if item deleted*
1	32.7857	96,769	0.285	0.108	0.685
2	36.7999	94,145	0.359	0.345	0.674
3	45.6544	79,446	0.567	1,000	0.899
4	37.8877	64,321	0.285	0.108	0.685
5	42.7180	94,145	0.459	0.345	0.674
6	30.6541	88,346	0.527	1,000	0.701
7	42.7654	82,769	0.285	0.108	0.685
8	39.7255	96,769	0.510	0.108	0.685
9	37.7329	94,145	0.322	0.345	0.674
10	40.6521	78,346	0.547	1,000	0.701

From table 5 above it can be seen that the value of r is 0.837. This means that the question is credible and included in the very high category. The results of this study produce a tool to measure the ability to solve mathematical problems in three-dimensional material, which are grouped into four competency components. These variables were developed according to the theory and framework provided, and after conducting the research, the main theoretical studies used were different from the previous studies mentioned above. The instrument has also gone through several stages of testing as a conditional test in the development of evaluation instruments. Based on these findings, three levels of validity were carried out in this study. The first is expert adequacy. Implementation of the effectiveness test by experts aims to assess the practical suitability of an item of equipment for each variable in accordance with the established theory and indicators (in this case the ability to solve mathematical problems). This is consistent with the finding (Nichols-Barrer et al., 2016)that relevance refers to relevance, importance, usefulness, character, diagnostic potential, practicality, and relevance. The next step is to check the adequacy of the contents of the expert evaluation results and update the examined instruments without further revision.

Testing the effectiveness of the content involves six validators, who assess each item according to a given rating scale, and the results are calculated using Aiken's V coefficient formula. This test is carried out to check the depth and relevance according to the scope of the indicators and the contents of the tool. The specific requirement of content validation is to provide a value that is used to determine the strength and breadth of the content

sufficiently and not out of bounds (Nichols-Barrer et al., 2016). Evaluators also provide comments and suggestions for improvement. These suggestions are used to improve the equipment in question. This is in accordance with the statement (Srirahayu & Arty, 2018) that expert reviewers provide evaluations and comments and suggestions for all instruments, and these suggestions are used as a basis for improving the rewriting of research instrument items.

Based on the results of the evaluator's evaluation analysis, it appears that the mathematical problem-solving ability variable can be classified as very effective. The revised instruments were tested in a study sample and the results were used to test the empirical or criterion adequacy. The goal is to determine the correlation value and internal consistency between items. As noted by (Mellinger & Hanson, 2020), the empirical validity value is obtained from the test results given to the respondents being evaluated. This test uses product-moment correlation which is analyzed with SPSS. Consequently, there was one invalid entry for item three in the mathematical problem-solving ability variable, which reversed the decision for that one entry. So for the mathematical problem solving ability variable, 9 items were validated.

After running a series of validity tests, the final step is the reliability test. Reliability test aims to determine the feasibility and effectiveness of an instrument as an evaluation tool. Reliability is done to determine a reliable measuring instrument (Leung, 2015). Reliability aims to see the correlation of items of equipment to what it actually measures (Maulida & Lubis, 2018). In this research, he uses Cronbach's alpha formula to perform reliability calculations on his SPSS application. The results of the analysis show a confidence value of 0.837, so that it can be said that the matter of mathematical problem-solving abilities developed can be relied upon to measure mathematical problem-solving abilities in three-dimensional material.

The next step is to determine the discriminating power of the problem. The discriminating power of the questions aims to determine the extent to which the questions developed can distinguish students with high abilities from students with low abilities. The results of calculating the discriminating power of each item are presented in Table 7.

Table 7. Distinguishing power test results Using SPSS 16 to determine the discriminating power coefficient

item th	***1***	***2***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
Diff inter	0.67 B	0.39 S	0.34 S	0.49 B	0.53 B	0.52 B	0.63 B	0.33 S	0.38 S

After knowing the discriminating power of each item, then the item difficulty index is determined. Table 8 shows the results of the difficulty index calculation.

Table 8. Difficulty test results Using SPSS 16 to determine the item difficulty index

item th	***1***	***2***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
Diffculty inter	0.27 Su	0.56 Se	0.48 Se	0.44 Se	0.30 Su	0.29 Su	0.43 Se	0.78 Your	0.81 Your

From Table 8 it can be seen that all items are moderately ranked (Items no. 2, 4, 5, and 8), in the easy category (Items no. 9 and 10), except for items 1, 6, and 7 which are categorized as difficult questions. Thus it can be concluded that all items can be used to measure mathematical problem solving abilities. Because the question number, namely at number 3, has been deleted (because it is invalid).

Conclusion

From the development stage of the means, it can be concluded that the instrument for mathematical problem solving abilities in three-dimensional material for class XII high school students can be classified as a valid tool for 9 questions, that is, it can be used by students as a means to measure mathematical problem solving abilities.

Suggestions for future researchers to develop tools for the same material to measure other different abilities such as comprehension, critical thinking and so on**.** Or it can also be used on other materials.

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