JEMS (Journal of Mathematics and Science Education), 11(1), 2023, 249-260
DOIs: 10.25273/jems.v11i1.14705

Development of High School Students' Mathematical Reasoning Ability Instruments on Three Dimension Material

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Abstract:
Tujuan penelitian ini adalah mengembangkan alat evaluasi pembelajaran matematika untuk mengukur kemampuan penalaran matematis siswa SMA. Jenis pengembangan yang diterapkan terkait dengan model yang dikembangkan oleh Thiagarajan. Populasi penelitian terdiri dari empat sekolah di Kota Pasuruan. Sampel penelitian ini adalah siswa kelas XII SMA YALC Pasuruan. Teknik pengumpulan data menggunakan instrumen penalaran matematis tentang materi tiga dimensi yang terdiri dari tiga soal deskriptif. Analisis data menggunakan validitas, reliabilitas, daya pembeda dan kesukaran. Hasil penelitian ini menunjukkan bahwa alat asesmen mengukur kemampuan penalaran matematis siswa SMA yang dikembangkan dengan baik dan layak sehingga dapat digunakan.

Kata Kunci : Instrumen test; Kemampuan Penalaran Matematis; Dimensi Tiga; Pengembangan

Abstract:
The purpose of this study was to develop an evaluation tool for learning mathematics to measure the mathematical reasoning abilities of high school students. The type of development applied is related to the model developed by Thiagarajan. The study population consists of four schools in Pasuruan City. The sample of this research was class XII SMA YALC Pasuruan. Data collection techniques used mathematical reasoning instruments about three-dimensional material consisting of three descriptive questions. Data analysis uses validity, reliability, discriminatory power and difficulty. The results of this study indicate that the assessment tool measures the mathematical reasoning abilities of high school students which are well developed and feasible so that they can be used.

Keywords : Test instruments; Mathematical Reasoning Ability; Dimension Three; Development

Introduction

Assessment is a series of activities carried out by the teacher to help students (Li et al., 2021; Zamanzadeh et al., 2015). Inappropriate test equipment also produces inaccurate results. Appropriate test preparation techniques provide a solid basis for functional evaluation. According to Rahi, (2017), measurement error is classified into two types: random error and systematic error. Random errors are caused by the physical and mental conditions tested and tested, while systematic errors can be caused by measuring devices. The question must be able to minimize the smallest possible error from the measurement results produced by the measuring instrument. According to Haryanti & Saputra, (2019), a good instrument must have three main characteristics: effectiveness, reliability, and ease of use. Test kits are one of the educational needs. Like the term education without measurement tools such as desalinated food, the teacher must be able to assess the learning outcomes that have been carried out. Evaluation is done to improve teaching and evaluation is done for teachers and students. This is in line with what was said by Otgonbaatar, (2021):" *Assessment information can help teachers determine what to teach, how to teach it, and how effective their teaching will be.*"

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The effectiveness of learning programs must be measurable in order to see students' understanding of facts, phenomena, principles, concepts, laws, theorems and their application. For this reason, a valid and reliable assessment is needed to measure the results and impact of learning. Assessment has three main functions (Hung & Wang, 2021; Inganah et al., 2023; Rizki et al., 2022; van der Lee et al., 2021), namely: (1) knowing the knowledge gaps that students have 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 (Choirudin et al., 2022; Fouryza et al., 2019; Sah et al., 2023; Sekaryanti et al., 2022).

Higher order thinking is one of the priorities in learning mathematics (Arisoy & Aybek, 2021; Darmayanti, Sugianto, et al., 2022; Fauza et al., 2022). One of the competency requirements for mathematics teachers is that teachers are able to understand, apply, and analyze knowledge of facts, concepts, procedures, and metacognition through experience. According to Bronkhorst et al., (2020), reasoning skills can be divided into low-level cognitive understanding and high-level reasoning. Lower-level thinking is remembering, understanding, and applying; higher order thinking is analyzing, evaluating, and creating. Reasoning is part of the higher order thinking process (ND Safitri et al., 2023; Sugianto et al., 2022). Argument is a thought process or activity to reach a conclusion. The above statement is supported by the statement Kabael & Akin, (2018):

"*Inference is the process of reasoning from a set of information*".

Students must be able to independently solve various problems and apply them to society through the information they have collected. If students have good reasoning abilities, they can solve problems well (Darmayanti et al., 2023; Wulandari et al., 2022). By providing inferences, students can develop the logical thinking skills necessary for problem solving. Therefore, to develop this reasoning ability it is necessary to provide tools. For learning, supporting tools include learning implementation plans (RPP), teaching materials, skills tools, and other tools (Suwarno & Aeni, 2021; Vidyastuti et al., 2022). These tools should be linked to indicators of developed reasoning skills. Measurable thinking skills are mathematical reasoning abilities, if these reasoning abilities are developed in mathematics.

Furthermore, according to González et al., (2021), dan Slovin, (2020), serta Sterner et al., 2020), inference in learning mathematics is a thought process that connects facts or evidence, and known evidence leads to a conclusion. So that mathematical reasoning is the ability to conclude, analyze, evaluate, generalize, connect, integrate, find solutions to non-routine problems, and justify or prove. All of these abilities do not occur independently but are interrelated (Anjarwati et al., 2023; Darmayanti, et al., 2022). A similar opinion was expressed by Xin et al., (2020)that reasoning is an important skill needed to understand mathematical concepts and apply ideas and practical procedures in mathematics to construct new knowledge.

In Casey et al., (2017), Darmayanti, et al., 2022, & Sumarmo, (2012)general, reasoning is divided into two, namely inductive reasoning and deductive reasoning. It further Brookman-Byrne et al., (2019)explains that inductive reasoning is defined as drawing general or specific conclusions based on observed data with a truth value that can be true or false. Activities that are included in inductive reasoning and are high-level thinking skills that are expressed by Weruin, (2017)consisting of analogies, namely drawing conclusions based on similarities in data or processes; generalization, namely drawing general conclusions based on a number of observed data; approximate answers, solutions or trends of interpolation and extrapolation; provide an explanation of existing models, facts, characteristics, relationships, or patterns; and use relationship patterns to analyze situations, and make guesses.

For deductive reasoning, Syaripuddin et al., (2020)states that a conclusion is a conclusion based on agreed principles with a truth value that is absolutely true or false and not both at the same time. Further explained by Merona & Santi, (2018), activities that are classified as deductive reasoning and are high-order thinking skills include drawing logical conclusions based on rules of inference, checking the validity of arguments, proving, and constructing valid arguments; develop direct proof, indirect proof and proof by mathematical induction

From the several opinions about reasoning abilities above, this study aims to produce valid and reliable tests of mathematical reasoning abilities in three-dimensional subjects, as well as to determine the discriminating power and level of difficulty of the items. This study aims to contribute to the field of mathematics, especially geometry. Mathematical reasoning ability in this essay is the ability to guide the mind to make statements in solving problems to arrive at a conclusion. When measuring thinking skills, the following indicators were observed: (1) presenting a mathematical solution; (2) file a complaint; (3) perform mathematical operations; (4) collect evidence related to the correct solution; (5) draw conclusions from the mathematical problems found; and (6) identify general patterns.

Method

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 et al., (1974). 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.

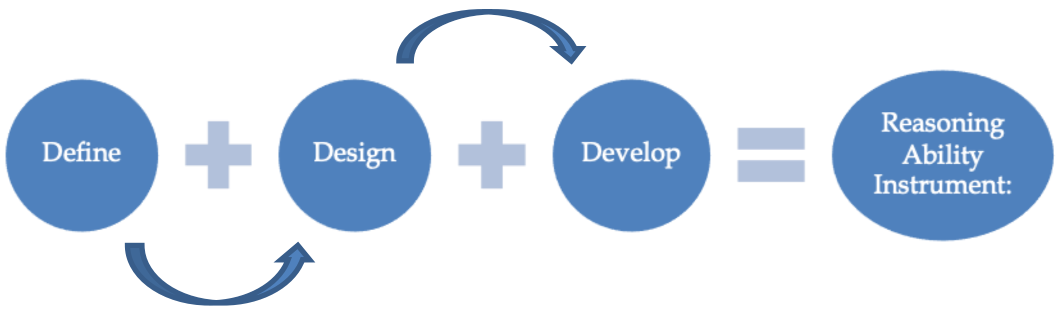

Figure 1. The flow of the stages of developing a Mathematical Reasoning Ability Instrument with the Theory of the Thiagaran model

The development of a mathematical reasoning test instrument requires qualitative and quantitative data. The design used is the (Samsul & Mutmainnah, 2018)plot exploration design described in Figure 2.

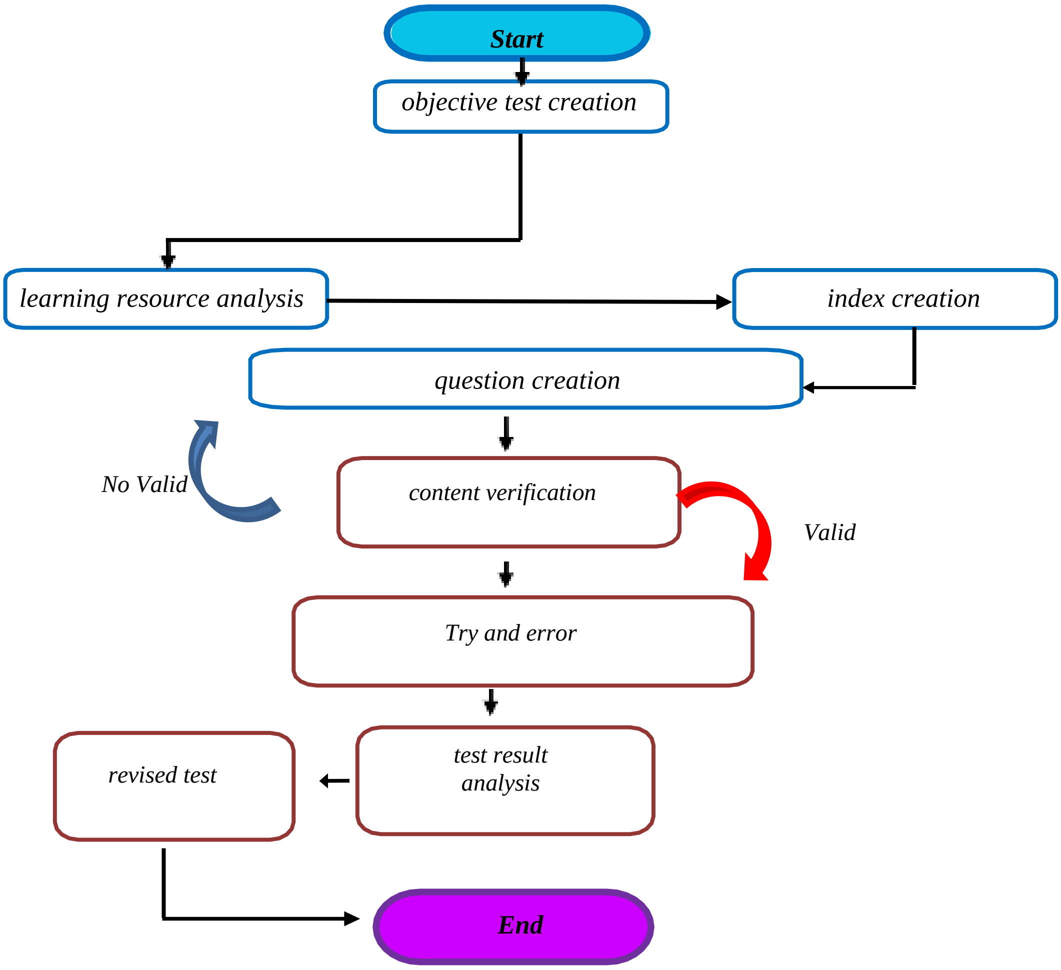

Figure 2. The procedure for making a mathematical reasoning ability test

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 about reasoning skills and material about three dimensions). This is in accordance with the works (Merona & Santi, 2018; Setiana, 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 was made based on the material lattice of differential equations and the mathematical reasoning ability index. 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. 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 reasoning 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 1 mathematics education practitioner. 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 α = 5%. If the significance of the calculation is greater than α = 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 10 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, and interpretation of the correlation coefficient follow the categories (Li et al., 2021; Srirahayu & Arty, 2018).

Results and Discussion

Results

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

1. Define

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

Table 1. Mathematical Reasoning Process Indicator

Mathematical Reasoning Process	Mathematical Reasoning Indicator
Make a Hypothesis	1) Learners have the ability to find various answers to difficulties based on their experience and expertise. 2) Students have the expertise to utilize mathematical models to make solutions to the difficulties they encounter.
Carry out mathematical manipulations	1) Learners can distinguish between those who have know and what to ask. 2) Learners can recognize the techniques used in solve the problem. 3) Students have the expertise to acquire new knowledge and abilities in accurately answering questions and using algorithms 4) Learners have the ability to understand and aptitude for problem solving techniques.
Interesting hypothesis	1) Students can use their investigations to draw conclusions, collect information, and provide justification or evidence for the accuracy of answers.
Create proof of solution validity	1) Students are able to think to empower knowledge in such a way as to produce a thought.
Draw conclusions from statements	1) Students are able to think to empower knowledge in such a way as to produce a thought
Investigate the validity of the	1) Students are able to use existing information to rework the problem in a different way.

argument	2)	Students are able to check the results of the answers to the questions.
identify	1)	Students are able to find patterns or properties of mathematical symptoms to make generalizations.

2. *Define*

The second stage is product planning. This activity aims to design an accurate reasoning 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 aim is to identify the issues involved in developing a test of mathematical reasoning. 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 10 students (limited trial). Based on the results of unstructured interviews with students that mathematical reasoning, 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 reasoning 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 roughly describe mathematical reasoning 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	5	5
Cochran's Q	3,000 [a]	4,000 [a.m]
df	6	6
Asym. Sig	.809	.677
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 0.809. The value of 0.809 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 reasoning ability instrument. Furthermore, in table 2, the results of the test scores for face validation on the *Asym.sig statistic* show a value of 0.677. The value of 0.677 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 face validity of the mathematical reasoning ability instrument. So, based on the overall results it can be concluded that the instrument for students' mathematical reasoning 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 10 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 Reasoning ability test instrument

Aspect	Indicator	Sub indicators	Score
Mathematical Reasoning	Make a Hypothesis	Students can submit possible answers that are correct, complete, and the final answer is correct	4
		Students can submit possible answers that are correct, complete, and the final answer is wrong	3
		Submit possible correct but incomplete answers or vice versa	2
		Proposes a possible wrong answer	1
		Students do not answer	0
	Carry out mathematical manipulations	Students can find the relationship between facts, concepts, principles in solving problems correctly, completely, and the final answer is correct	4
		Students can find the relationship between facts, concepts, principles in solving problems correctly, completely, and the final answer is wrong	3
		Learners can find relationships between facts, concepts, principles in solving problems but there are some mistakes	2
		Learners can find relationships between facts, concepts, principles in solving problems but wrong	1
		Students do not answer	0
	Interesting hypothesis	Students can compile evidence, provide reasons or evidence for several solutions correctly, completely, and the final answer is correct	4
		Students can compile evidence, provide reasons or evidence for several solutions that are correct, complete, and the final answer is wrong	3
		Compile evidence, provide reasons or evidence against several solutions but there are some errors	2
		Arranging evidence, giving reasons or evidence against several solutions but wrong	1
		Students do not answer	0
	Able to make conclusion	Students can draw conclusions from statements correctly, completely, and the final answer is correct	4
		Learners can draw conclusions from statements	3

	s from mathematical problems that have been found	correctly, completely, and the final answer is wrong	
		Students can draw conclusions from statements but there are some errors	2
		Students can draw conclusions from statements but are wrong	1
		Students do not answer	0
	Able to identify patterns in general	Determine the pattern or method of a statement and be able to draw general conclusions that are correct, complete, and the final answer is correct	4
		Determine the pattern or method of a statement and be able to draw general conclusions that are correct, complete, and the final answer is wrong	3
		Determining the pattern or way of a statement and being able to draw general conclusions but there are some errors	2
		Determining the pattern or method of a statement and being able to draw general but wrong conclusions	1
		Students do not answer	0

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	0.758	Tall
2	0.429	Enough
3	0.573	Enough

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 reasoning 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 mathematical reasoning ability 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*
0.743	0.802	3

From table five it can be seen that Cronbach's alpha for the whole is 0.743, so it can be said that the reliability of examining mathematical reasoning abilities is very high. From calculations with Cronbach's alpha, it can also be seen which objects need to be removed, changed or revised. This is determined from the Cronbach's Alpha fee if the Item is Deleted, if the fee is more than 0.743 then the object needs to be deleted, changed or revised. In table 5 it can be seen that each object has a Cronbach's Alpha value. If the deleted items are less than 0.743, it can be said that each object object no longer has to be deleted, changed, or revised.

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	34.7999	94,145	0.359	0.345	0.674
3	40,654	78,346	0.567	1,000	0.701

In Table 6 it can be seen that all items are less than 0.743 if the Cronbach's alpha value when the item is removed is less than 0.743. so you can say you don't need to delete, replace or modify each question item. Based on the calculation results above, it can be said that the problem of mathematical reasoning ability developed can be relied upon to measure mathematical reasoning ability 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*	*3*
Diff	0.67	0.42	0.56
inter	B	S	B

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*	*3*
Diffculty	0.27	0.47	0.59
inter	Hard	Currently	Easy

From Table 8 it can be seen that all items are moderately ranked, except item 1 which is categorized as difficult questions. Thus it can be concluded that all items can be used to measure mathematical reasoning abilities.

Conclusion

From the stage of developing the means, it can be concluded that the instrument of mathematical reasoning ability in three-dimensional material for class XII high school students can be classified as a valid tool, that is, it can be used by students as a means to measure mathematical reasoning ability.

Suggestions for future researchers to develop tools for the same material to measure other different abilities such as comprehension, solving, critical thinking and so on.

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