26 (2), 2025, 1173-1195

Jurnal Pendidikan MIPA

e-ISSN: 2685-5488 | p-ISSN: 1411-2531
https://jpmipa.fkip.unila.ac.id/index.php/jpmipa

Measuring Creative Thinking Skills Using the Feasibility of Mathematics Problems with an Open-Ended Approach in Two-Dimensional Plane Geometry Topic

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Abstract: The study aims to develop and validate open-ended mathematics questions, where measuring students' abilities at the field test stage is part of the final validation process to show that the instrument is functional. The development model with Tessmer's formative evaluation approach includes self-evaluation, expert review, one-to-one, small group, and field tests. The participants included one lecturer, two mathematics teachers, and students from grade IX. Individual trials involved three students, small group trials 12 students, and field trials 40 students. The data obtained came from quantitative and qualitative data. The instruments used included observation sheets, interviews, questionnaires, and tests. Analysis for quantitative data was carried out using the SPSS application. The findings of the study indicate that (1) this study produces a mathematics question product with an open-ended approach of 5 descriptive questions. Content validity (90.33%), construct validity (94.25%), and language validity (92.25%). High validity is caused by the formulation of questions that explicitly ask students to provide various ways, which directly target indicators of fluency and flexibility in creative thinking. In addition, the validity of each question item in the small group, namely r count > r table (0.576), with a reliability value of 0.931. (2) Open-ended math questions that are valid and reliable, so that they are used to measure students' creative skills in problem solving. Based on the results of the field test (20% of students are very creative, 30% creative, 10% quite creative, 5% not creative, and 5% very not creative), this proves that the instrument developed is able to differentiate the level of student ability. This study concludes that the development of math questions with an open-ended approach is feasible to be applied to measure creative thinking skills in solving math problems related to the two-dimensional plane geometry topic.

Keywords: creative skills, feasibility of mathematical problems, open-ended approach, two-dimensional plane geometry topic.

▪ INTRODUCTION

Students often consider mathematics difficult, complicated, and boring because it requires complex thinking in solving problems. Difficulties in learning mathematics arise from complicated formulas and calculations, which require the use of creative thinking to solve problems. Creative thinking skills play a vital role in the process of solving mathematical problems (Heong et al., 2011). Creative thinking is one of the basic skills that need to be mastered in the 21st century, especially in the field of mathematics (Çelik & Özdemir, 2020). Creative thinking skills in mathematics are essential for all students (Aini et al., 2019). The main objective of mathematics lessons is to improve the application of knowledge and skills that have been acquired in solving everyday problems (Stacey & Turner, 2015). Students who have creative thinking skills have high sensitivity to various problems, are able to see from various points of view, and analyze each step in solving problems (Maričić1, Špijunović1, & Lazić2, 2015).

Creative thinking skills are key skills in learning mathematics and are closely related to the ability to identify and solve problems (Gafour & Gafour, 2020).

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DOI: http://dx.doi.org/10.23960/jpmipa/v26i2.pp1173-1195
Received: 16 June 2025
Accepted: 03 July 2025
Published: 11 July 2025

Mathematical creative thinking refers to the ability to find new and varied solutions to unsolved mathematical problems or to look at mathematical problems from a different perspective and come up with unusual solutions (Silva, Lopes, Dominguez, & Morais, 2022). From this opinion, it can be concluded that problem-solving ability can be seen as a container where creative thinking is expressed. This implies that the problem-solving process not only involves the application of existing solutions but also requires the ability to think outside the box, generate new ideas, and find innovative ways to overcome challenges. Problem-solving skills are essential in mathematics because they are a tool for applying mathematical concepts (Bahar & Maker, 2015).

One of the goals of teaching mathematics is to develop creative thinking skills in students (Hadar & Tirosh, 2019; Suherman & Vidákovich, 2022). Through learning mathematics, students are trained to think logically, analytically, critically, and creatively in solving problems so that, in the end, students can develop better problem-solving skills (Aldiono, Purnomo, & Prastowo, 2023; Bora, 2020; Cotič, Doz, Jenko, & Žakelj, 2024; Lince, 2016). Indicators of problem-solving skills include understanding the problem, the ability to design solutions, and the ability to implement plans that have been made (Palennari, Lasmi, & Rachmawaty, 2021).

In reality, the creative thinking skills of Indonesian students in mathematics learning are still low. Indonesian students are participating in PISA 2022, which, for the first time, includes an assessment of creative thinking skills (OECD 2022, 2022). PISA 2022 emphasizes creative, flexible thinking and development through practice (OECD, 2024). However, the PISA results show that Indonesia is still ranked low in critical thinking skills. Indonesia is ranked 69th out of a total of 80 countries that participated in the PISA survey (OECD 2022, 2022). This proves that students' ability to think creatively still does not meet expectations. Thus, creative thinking skills, especially in mathematics, still need to be improved. The ability to think creatively is present from birth and can be improved through various activities (Anwar, Aness, Khizar, Naseer, & Muhammad, 2012). One approach used to encourage students to think creatively is the open-ended mathematics approach. Referring to research (Suherman & Vidákovich, 2022), it is stated that open-ended questions can be used to measure creative thinking skills in mathematics. Open-ended questions do not have one definite answer, thus encouraging the emergence of creative thinking. (Rahayuningsih, Sirajuddin, & Ikram, 2021) Found that the open-ended approach can be used to measure students' mathematical creative thinking abilities. (Christopher, Julie, Charity, & Janehilda, 2020; Heliawati, Afakillah, & Pursitasari, 2021) stated that the open-ended approach in mathematics learning provides opportunities for students to explore various solutions and strategies to solve problems. Mathematics with an open-ended approach can encourage students to think creatively (Munahefi, Mulyono, Zahid, Syaharani, & Fariz, 2021; Munroe, 2015; Rizos & Gkrekas, 2023). Teachers need to guide students to use various strategies so that students can find the correct and varied answers (Dermawan & Andartiani, 2022). (Emara, Hutchins, Grover, Snyder, & Biswas, 2021; Munroe, 2015) revealed that the open-ended approach includes problems that can have more than one correct answer. Students answer the questions in their own way, not with the methods that have been taught before (Randles, Overton, Galloway, R., & Wallace, 2018). The goal of learning mathematics with an open-ended approach is to improve students' creativity and mathematical thinking through collaboration in solving problems (Moate, Kuntze, & Chan, 2021).

The urgency of open-ended mathematical inquiry encourages deeper mathematical thinking, enhances creativity, fosters critical thinking skills, and allows for multiple solutions and approaches to solving problems, ultimately leading to a more engaging and enriching learning experience for students compared to traditional closed questions (Aziza, 2021; Rizos & Gkrekas, 2023). Many researchers have widely revealed several previous studies on mathematics subjects. The results of the study show that many students consider mathematics lessons difficult and complex (Raupu, Nurdin, Hasriana, & Said, 2023). Mathematics lessons are a tough challenge for most students because they are difficult (Langoban, 2020). Solving math problems requires a variety of skills that may not be possessed by all students, and many students struggle to grasp math concepts. This can be due to a number of factors, such as a lack of understanding of basic concepts, difficulty applying knowledge, or lack of practice in problem solving (Adelabu & Alex, 2023). In addition, one of the common challenges faced by students is the difficulty of working on story problems (Khoerunnisa, 2021). Story problems are given to students with the aim of training them in solving mathematical problems that are relevant to everyday life (Era Setiyawati, Endang Fauziati, Darsinah, Minsih, & Yenny Prastiwi, 2022). The types of errors that occur when solving story problems can be divided into five categories, namely errors in understanding the context, errors in understanding, errors in changing story problems into mathematical models, errors in process skills, and errors in writing answers (Nathan, 2004; Yunus, Zaura, & Yuhasriati, 2019). Difficulty understanding math formulas is a common problem faced by students. This can be caused by a variety of factors, including a lack of understanding of basic concepts, ineffective teaching methods, or a lack of motivation (Wati, Fitriana, & Mardiyana, 2018).

This reality implies a gap between students' expectations and reality. It is expected that students have a strong foundation of understanding mathematics, can handle various types of mathematics problems, including story problems, well, can apply mathematical concepts in everyday life, like mathematics lessons, and are motivated to learn. However, in reality, many students feel that mathematics is a complex and challenging subject; students have difficulty in understanding problems, especially story problems; students are not careful in reading and understanding problems; students find it challenging to apply and memorize mathematical formulas in solving problems; students have low interest in mathematics; and the learning process is often less interactive, as there is a difference between the material taught in school and the context of students' real lives.

Based on the description above, several research questions arise. 1) What are the characteristics of valid and reliable open-ended mathematics questions to measure junior high school students' creative thinking skills on the two-dimensional plane geometry topic? 2) How is the feasibility of the questions developed based on expert reviews and student trials? 3) How is the profile of students' answers that show various levels of creative thinking skills when measured using the developed instrument?

▪ METHOD

This research is included in the category of research with an educational design research (EDR) approach, with a development type (development studies) that aims to determine the feasibility of mathematics problems with an open-ended learning approach to measure creative thinking skills in solving mathematical problems.

Participants

Participants in the development research for validation involved a lecturer and two mathematics teachers. Three students were needed for individual product trials, twelve students were needed for small group trials, and forty students were needed for field trials. This study used a sample of 40 ninth-grade students in Surabaya, taken from a population of 110 ninth-grade students in Surabaya. The sampling technique used was cluster random sampling. This means that the students were taken randomly from several classes, not from the entire population individually. The instruments used in this study included test instruments, namely written tests on mathematical creative thinking skills with questions that were in accordance with aspects of creative thinking skills and had been tested on classes that were not samples. The test instrument on mathematical creative thinking skills was previously tested on classes that were not samples to measure its validity and reliability. The place where this research was conducted was at a junior high school in Surabaya, and the implementation time was from February to June 2025.

Research Design and Procedures

The data obtained from this study includes quantitative and qualitative data. Quantitative data is information that is measured in the form of numbers. The data is obtained from 1) question validation carried out by the validator and 2) the results of the assessment questionnaire given by students. To collect these two types of data, several research tools are used, namely, 1) question validation sheets, 2) student response questionnaire sheets, and 3) student learning achievement tests. Meanwhile, qualitative data is presented in the form of narratives or words, not numbers. This qualitative data includes input or comments obtained from validation carried out by experts, test construction experts, language experts, and student response questionnaires. The research development design applied is a preliminary and formative evaluation, according to Martin Tessmer. In the preliminary stage, the researcher analyzed the curriculum related to the two-dimensional plane geometry topic in grade IX according to the “Merdeka” curriculum. Furthermore, the researcher compiled open-ended questions according to the topic and creativity indicators that were to be improved. The formative evaluation stage includes self-evaluation, expert review, one-to-one, and small group (Amelia, Widiati, & Yadrika, 2023; Zulkardi & Kohar, 2018).

The procedure in this study is divided into two important parts, namely the preliminary stage and formative evaluation. The preliminary stage of the research consists of the initial needs analysis stage for teachers and students and the initial design stage (prototyping), while the formative evaluation stage consists of self-evaluation, expert review, one-to-one, small group, and field testing. The preliminary stage is the stage where an initial analysis is carried out on the two-dimensional plane geometry topic for grade IX, according to the “Merdeka” curriculum. Some questions for the initial needs analysis, such as do students like mathematics? has the two-dimensional plane geometry topic been taught this semester? do students like the geometry topic? do students understand math problems with an open-ended approach? is learning mathematics with an open-ended approach fun?. Furthermore, the location and subject of the research are determined, and coordination is carried out with the teaching staff and the school where the learning takes place. The next stage is the design stage, which includes creating initial questions (first prototype). This initial prototype is carried out by compiling math problems using an open-ended approach.

The formative evaluation stages include self-evaluation, expert review, one-to-one, small group, and field testing. After that, a field trial was conducted involving more students. The purpose of the field trial was to determine the impact of math problems using an open-ended approach in measuring students' creative thinking skills and problem-solving abilities. Figure 1 shows the design flow in developing math problems.

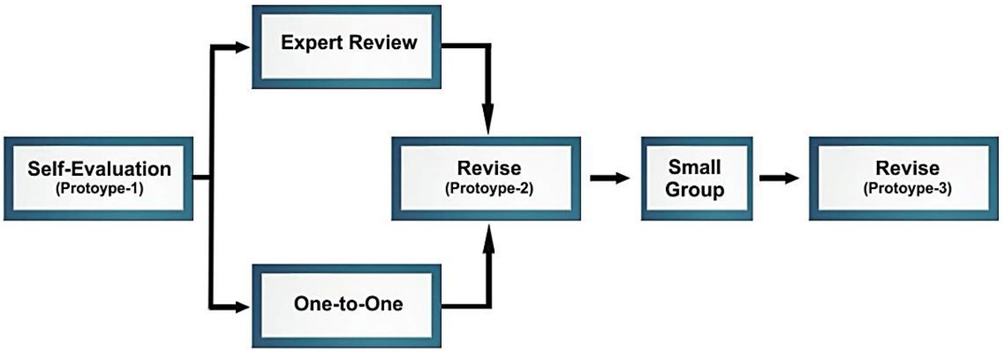


Figure 1. Design flow in developing mathematics problems

Based on the design flow above, the data collection technique is detailed at each stage. Self-Evaluation Stage: At this stage, the design of mathematics questions uses an open-ended approach by considering the characteristics of mathematics questions, namely paying attention to the type of question, content, construction, and language used. The product resulting from self-evaluation is prototype 1. Expert Review Stage. At this stage, prototype one is submitted to experts, consisting of one lecturer and two mathematics teachers who act as validators. To become a validator of open-ended mathematics questions, an expert must have at least the following qualifications: a deep understanding of open-ended mathematics, experience in developing open-ended questions, and the ability to assess the validity, practicality, and effectiveness of open-ended mathematics questions. Experts were asked to conduct a qualitative analysis related to the construct, content, and language validity of the mathematics problems using the open-ended approach that had been developed. Construct validity is related to the suitability of the indicators of creative thinking in problem solving. Content validity is related to the suitability of the topic in the “Merdeka” curriculum. Language validity includes suitability with applicable language rules. The input results from the experts are called Prototype II. The one-to-one prototype-2 stage was distributed to three students who had varying levels of ability. Interviews were conducted to explore information on the readability of mathematics problems using the open-ended approach. Examples of questions are as follows: Which part of the problem is the most confusing, or do you understand the most? Are there any terms in the problem that confuse you? Do you feel that there is missing information in the problem?

Small Group Stage. At this stage, prototype II questions were tested on 12 students. The goal to be achieved was to find out how practical the questions were. While students were working on the questions, the researcher observed if there were any students who faced various difficulties in answering open-ended questions. Students were also asked to provide input related to the questions they were working on. Input from students was used as a consideration in improving prototype II. The results of the improvements to prototype II are known as prototype III, at the field test stage. At this stage, prototype III was tested on all students in grade IX in Surabaya. The trial was conducted to see if the instrument functioned in real conditions, similar to the situation in which the instrument would be used operationally. This is in accordance with the type of research with the Educational Design Research (EDR) approach, with the development type (development studies), namely a research approach that aims to develop research-based solutions to problems in educational practice.

All ninth-grade students involved in this study had previously been tested through a pretest. This was done intentionally by the researcher to see whether all students had initial abilities. Thus, students in the small group and field tests had similar abilities. The open-ended math problems used for the pretest had slight differences from the problems used by students for the small group and field tests.

Instrument

The data collection instruments in this study were validation sheets, interviews, observations, and problem-solving ability test sheets. The validation sheets were designed using a common standard Likert scale (4, 3, 2, 1) with the following criteria: 4 (Very Good), 3 (Good), 2 (Poor), and 1 (Very Poor). Experts validated the open-ended mathematics problem scripts by considering the appropriateness of the content, construct, and language. The grid for the validation sheet is presented in Table 1. The interviews conducted in this study used unstructured interviews. Interviews were conducted to determine the characteristics, learning models, and abilities of students. Observation sheets were used to observe student activities in class when studying the two-dimensional plane geometry topic. The grid for observations can be seen in Table 2. The ability test in solving mathematics problems with an open-ended approach was carried out in several stages. The validation stage of the mathematics test was carried out by one lecturer and two mathematics practitioners, followed by the stage of implementing the test individually, in small groups, and finally in the field test stage, which is a systematic process to ensure the validity and reliability of the test. This aims to test various aspects of the test and ensure that the test is in accordance with the desired objectives and can be applied in various situations. For the validity test of the test items using product moment correlation and the reliability test using alpha Cronbach with the number of 5 questions each.

Data Analysis

The data analysis process was carried out by examining the validation results from experts, individual trials, small groups, and field tests, which were then used to revise the questions that had been prepared by the researcher. The data were analyzed using a qualitative descriptive approach to explain the results of each development step in this study.

The comments given by the validator can be categorized into several parts, namely: 1) clarity of sentences in math problems, 2) use of more transparent and more attractive colors, 3) directions to encourage students to give more than one correct answer, and 4) instructions on the picture (numbers and letters) to facilitate student understanding. The decision to revise is determined by the quality of the question; if the question is not included in the established category, the researcher will make improvements, but if the question is in accordance with the existing category, revision is not necessary. After data processing, quantitative data analysis was carried out with the help of SPSS 16.0 software.

For the analysis of the validity of the questions, the product-moment correlation was used, while the reliability of the questions was assessed using Cronbach's alpha. The results of the data analysis were then used to identify whether there was an impact of mathematics questions with an open-ended approach on students' creative thinking skills in solving problems.

Table 1. Expert validation grid

Aspect		Indicator
Content Assessment	1	Questions can be used to assess students' creativity.
	2	Questions have problem-solving characteristics.
	3	Questions allow students to find more than one correct answer.
	4	Questions can be solved using various solving strategies.
	5	Questions are in accordance with students' cognitive development.
	6	Questions can be used to assess students' creativity.
Construct Assessment	1	Problems allow students to use mathematical creativity to solve them.
	2	Problems allow students to connect content and context in finding mathematical relationships or generalizations.
	3	Problems can be solved using a variety of problem-solving strategies.
	4	Problems are structured using enough information to solve them.
Language Assessment	1	Questions are in accordance with Indonesian language rules.
	2	The language used is communicative.
	3	Sentences in questions do not give rise to multiple interpretations.
	4	The use of images, tables, or graphs as question information is appropriate.
	5	Sentences in questions are in accordance with students' cognitive development.

The feasibility test was conducted by a team consisting of one lecturer and two mathematics teachers before the development and implementation of mathematics problems with an open-ended learning approach. This feasibility assessment used several questionnaires that aimed to evaluate whether mathematics problems with an open-ended approach could measure creative thinking skills and mathematical problem-solving skills that had been developed so that they were feasible to be implemented. In this study, several instruments used included observation sheets, interviews, questionnaires, and tests. Observation sheets were used to observe student's activities in class when studying the two-dimensional plane geometry topic. The grid for observation can be seen in Table 2.

Table 2. Observation grid

No	Question
1	Students actively participate in mathematics learning.
2	Students understand mathematics problems with an open-ended approach.
3	Students work on mathematics problems in various ways.
4	Students think creatively to solve mathematics problems.
5	Students enjoy being able to solve mathematics problems.

The use of instruments to determine students' responses related to mathematics problems with the open-ended approach was developed. The individual and small group instrument grids are presented in Table 3.

Table 3. Individual and small group trial grid

No	Aspect	Indicator	
1	Open-ended approach to math problems.	a	clarity of questions in math problems.
		b	clarity of commands in math problems.
		c	clarity of images in math problems.
		d	math problems are in accordance with the two-dimensional plane geometry topic.
2	Creative thinking skills in solving problems.	a	open-ended math problems encourage students to think creatively.
		b	students think creatively in solving math problems in various ways.
		c	students can solve math problems in more than two ways.

Students filled out a questionnaire to obtain an objective assessment of mathematics problems with an open-ended approach. Data collected from each stage of the development of this mathematics problem script were analyzed qualitatively and descriptively. The interpretation of validity obtained from the expert review and minor review stages is as follows: Very good criteria with a score of 81% - 100%, good criteria with a score of 61% - 80%, fairly good criteria with a score of 41% - 60%, a score of 21% - 40% gets poor criteria, and 0% - 20% the criteria are very poor (Setyaedhi & Pramana, 2024).

The aspects that must be possessed in a mathematical creative thinking ability test instrument consist of fluency, flexibility, originality, and elaboration. These four aspects are stated in open-ended questions (Munahefi et al., 2021). To assess the level of students' mathematical creative thinking, it can be seen in Table 4 below.

Table 4. Assessment rubric for creative thinking skills in mathematics

Indicator	Score				
	0	1	2	3	4
Fluency (ability to solve problems, provide multiple answers, and provide examples related to mathematical concepts).	No fluency was shown in the answers.	One method is used to solve the problem, and the answer is wrong.	One method is used to solve a problem, and the answer is correct.	More than one way is used to solve a problem, and multiple answers are correct.	Students can solve problems with multiple answers and solve problems with the correct strategy.
Originality (the ability to produce unique	No originality is shown in the answer.	The originality shown in the answer is not	Originality is shown in the answer, but	Originality is shown in the answers, and	Students can show the problems in

and different answers).		original, and the answer is wrong.	the answer is wrong.	some answers are correct.	the questions correctly, can provide the correct answers, the solution strategies, and the results are correct.
Flexibility (ability to use various problem-solving strategies and provide various examples and statements in mathematics).	No flexibility was shown in the answers.	One method is used to solve problems and correct wrong answers.	One method is used to solve the problem and find the correct answer.	At least two different methods are used to solve the problem, and multiple answers are correct.	Students can solve problems using various problem-solving strategies and answer problems correctly, including making conclusions.
Elaboration (ability to develop detailed answers)	No explanation.	Inaccurate explanation, difficult to understand, and wrong answer.	The explanation is not quite right; it is difficult to understand, but the answer is correct.	The explanation is not precise, easy to understand, and the answer is correct.	Students can identify the problems in the questions correctly, can provide correct and detailed answers, and choose detailed solution strategies, and the results are correct.

Source: (Febriani & Hendra Syarifuddin, 2021)

Based on the description above, the researcher wants to know the mathematical creative thinking ability of grade IX students at junior high schools in Surabaya on the two-dimensional plane geometry topic. Students' mathematical creative thinking ability is obtained from the average score of the field test trial, where students' scores are converted into a range of 0-4 according to the assessment rubric that has been determined above. For an average score of 0, it is included in the very uncreative category; an average score of 0.1–1 is in the uncreative category; an average score of 1.1–2 is in the fairly creative category; an average score of 2.1–3 is in the creative category; and an average score of 3.1–4 is included in the very creative category.

▪ RESULT AND DISSCUSSION

The math problems designed in this study are math problems with an open-ended approach. The stages in the research and development of Tessmer's formative evaluation type are self-evaluation and prototyping (expert review, one-to-one, small group, and field test). In this process, the questions that have been created by the researcher will be validated, evaluated, and revised. The following are the results of each stage.

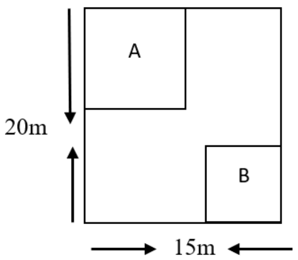
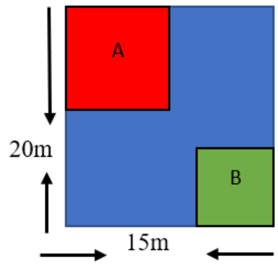
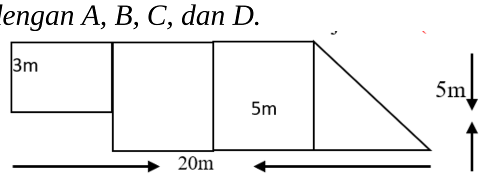
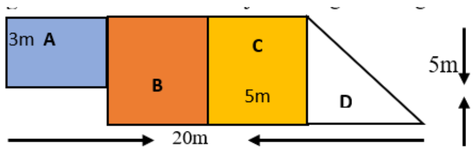
Self-Evaluation

This stage is divided into two parts, namely the analysis stage and the design stage. Analysis Stage: In the analysis stage, the researcher conducts curriculum analysis, material analysis, and student analysis. 1) Material Analysis. The material in this study is plane figures. Plane figures are given to students in grade IX in the even semester. In the plane figure material, the properties of plane figures, determining the area of plane figures, and determining their circumference have been explained. In the topic of plane figures, a method for determining the area of a plane figure is also included if the side of a plane figure is known. 2) Student Analysis. At this stage, an analysis is carried out on students. The student analysis in question is to determine students who will do one-to-one, small group, and field tests. Students who complete these stages are selected from different classes. Students who do the one-to-one stage are selected; 1 student from class IX A. Meanwhile, for the small group stage, six students are selected from class IX B, and for the field test stage, 1 class is selected from IX C. For the selection of the one-to-one stage, students are selected on the condition that they have taken the plane figure topic. In the small group stage, students are selected differently from the field test stage, but the students have similar characteristics. Classes IX A and IX B are classes that have similar characteristics in academic aspects. All students in class IX have also studied the two-dimensional plane geometry topic. Design Stage: At this design stage, the grid is compiled, the development of mathematical questions with an open-ended approach, and the preparation of assessment instruments is carried out. 1) The compilation of the question grid in this study is the same as compiling grids in general. The contents of the mathematical question grid in this study include core competencies, basic competencies, indicators, question forms, and question items. 2) The development of mathematical questions with an open-ended approach in this study resulted in five questions. All questions used have a descriptive format. 3) Preparation of assessment instruments. At this stage, the assessment instruments are prepared. The preparation of this assessment instrument is carried out after the researcher develops mathematical questions with an open-ended approach. This assessment instrument is prepared as a reference for measuring creative thinking skills in solving mathematical problems.

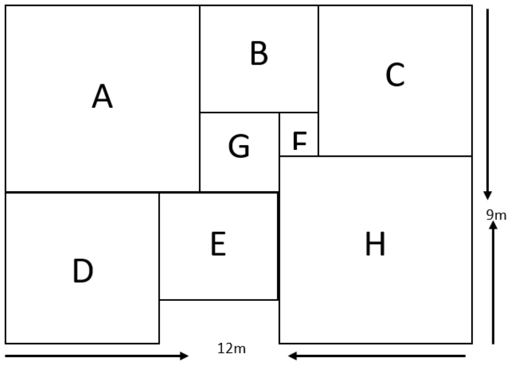
Prototyping

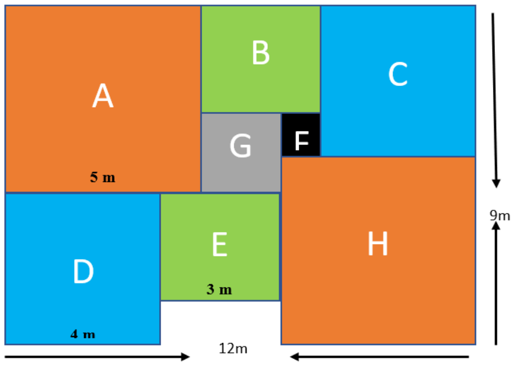
In this process, there are three stages, namely expert review, one-to-one, and small group. Expert Review. At this stage, the researcher validates the mathematics problems with the open-ended approach that has been designed. Mathematics problems using the open-ended approach developed by the researcher are assessed by validators consisting of one lecturer and two mathematics teachers. Validation is carried out to obtain input on the mathematics problems that have been created. Input from the validator, as well as notes on the question sheet and assessment guidelines, will be used as material for improvement for mathematics problems with the open-ended approach developed by the researcher. The following are mathematics problems with the open-ended approach before validation and after the validation process; see Table 5.

Table 5. Validation assessment by expert

No	Before Validation	After Validation
1	*Asep memiliki sebidang tanah, dengan panjang 20m dan lebar 15m, kemudian tanah tersebut dibagikan kepada A dan B. Hitunglah luas sisa tanah, Asep. Kerjakan lebih dari 2 jawaban (berikan warna supaya lebih jelas)* 	*Asep memiliki sebidang tanah dengan panjang 20m dan lebar 15m, kemudian tanah A dan B telah dijual. Hitunglah luas sisa tanah, Asep. Kerjakan dengan berbagai macam cara dengan benar.* 
2	*Alex mempunyai tanah dengan bentuk seperti gambar di bawah. Hitunglah luas tanah, Alex. Usahakan lebih dari 2 jawaban (berikan warna supaya lebih jelas). Berikan masing-masing bidang dengan A, B, C, dan D.* 	*Alex mempunyai sebidang tanah A, B, C, dan D dengan bentuk seperti gambar di bawah. Hitunglah luas tanah, Alex. Kerjakan dengan berbagai macam cara dan benar.* 
3	*Buatlah macam-macam bagung datar seperti; segi empat, trapesium, segitiga, jajar genjang dll (bangun datar) matematika dengan keliling 300 180cm. Buatlah lebih dari 2 bangun datar.*	*Buatlah macam-macam bentuk bangun datar matematika yang kamu ketahui dengan keliling 180cm. Buatlah sebanyak mungkin bangun datar.*
4	*Roy mempunyai ruangan berbentuk persegi panjang berukuran 1m x 1m. Roy akan memasang keramik di lantai tersebut. Bantulah Roy untuk. Hitunglah berapa jumlah keramik yang dibutuhkan untuk menutupi lantai tersebut. Keramik dalam ukuran cm.*	*Roy mempunyai lantai berukuran 1m x 1m. Hitunglah berapa jumlah keramik yang dibutuhkan untuk menutupi lantai tersebut. Keramik dalam ukuran cm. Kerjakan dengan berbagai macam cara dengan benar.*
5	*Perhatikan beberapa empat persegi sama sisi di bawah ini. Luas A sama dengan luas H, luas B sama dengan luas E. Luas C*	*Perhatikan beberapa empat persegi sama sisi di bawah ini. Luas A = H, luas B = E. Luas C = D. Berapakah luas G?*

sama dengan luas D. Luas A = H, luas B = E. Luas C = D Berapakah luas G? Kerjakan lebih dari 2 jawaban. Berikan angka-angka. Berikan warna yang luasnya sama supaya lebih jelas.	*Kerjakan dengan berbagai macam cara dengan benar.*





The assessment conducted by the validators on the mathematics questions using the open-ended approach created by the researchers included three aspects, content, construct, and language. Based on the results of the validation of mathematics questions using the open-ended approach, the questions compiled by the researchers were declared to meet the valid criteria with a total average of 92.26%. The validators' assessment result of the open-ended questions can be seen in Table 6.

Table 6. Validator's assessment of open-ended mathematics problems

Aspect		**Indicator**	**Percentage per Indicator**	**Percentage per Aspect**
Content Assessment	1	Questions can be used to assess students' creativity.	95%	90.33%
	2	Questions have problem-solving characteristics.	85%	
	3	Questions allow students to find more than one correct answer.	85%	
	4	Questions can be solved using various solving strategies.	90%	
	5	Questions are in accordance with students' cognitive development.	90%	
	6	Questions can be used to assess students' creativity.	97%	
Construct Assessment	1	Problems allow students to use mathematical creativity to solve them.	95%	94.25%
	2	Problems allow students to connect content and context in finding mathematical relationships or generalizations.	95%	
	3	Problems can be solved using a variety of problem-solving strategies.	90%	
	4	Problems are structured using enough	97%	

		information to solve them.		
Language Assessment	1	Questions are in accordance with Indonesian language rules	97%	92.2%
	2	The language used is communicative	97%	
	3	Sentences in questions do not give rise to multiple interpretations	85%	
	4	The use of images, tables, or graphs as question information is appropriate	97%	
	5	Sentences in questions are in accordance with students' cognitive development	85%	
Final Percentage of Validation Results				92.26%

The assessments conducted by three experts on content, construct, and language are as follows: content assessment (90.33%), construct assessment (94.25%), and language assessment (92.22%). Assessments by three students on individual trials (91.36%) and assessments by 12 students on small groups (91.71%). The validation results conducted by experts and students were each categorized as very good for mathematics problems with an open-ended approach. Thus, mathematics problems are feasible to be developed. The feasibility test uses calculations of all aspects using a questionnaire. 4. One-to-One. In the one-to-one stage, the researcher asked three students as testers. Students worked on math problems with an open-ended approach and provided comments on the problems given. Student comments were used as one of the materials for revising math problems with an open-ended approach. The revised problems were called Prototype II. The revision decisions are shown in Table 7.

Table 7. Revision decision

No	**Revision Decision**	**Questions Number**				
		1	**2**	**3**	**4**	**5**
1	Clarify the meaning of the question.	v	v	v	v	v
2	Change the context of the question in the question.	v	v	v	v	v
3	Color the image to make it more transparent and more interesting.	v	v			v
4	Clarify the instructions to do it in various ways correctly.	v	v	v	v	v
	Give the letters A, B, C, and D on the image to make it easier for students to understand.		v			
5	Provide a little information about the numbers in the image to make it easier for students to understand.					v

Small Group

At this stage, the researcher asked 12 students to work on and provide input on mathematics problems with an open-ended approach. Prototype II contains five mathematics problems in the form of descriptions. The results of the small group trial will be empirically validated, and the reliability value will be calculated. Based on the results of the small group trial for mathematics problems with an open-ended approach that the researcher has developed, it meets the reliability standard because the Cronbach's alpha value is 0.931 > 0.60, so it can be concluded that the five mathematics problems with an open-ended approach are reliable with a very high category.

Based on the responses of the trial students, the readability of the questions that have been developed is good. Students feel challenged when working on the questions. Mathematics questions with an open-ended approach that were tested on small groups of students at junior high schools in Surabaya, which met the validity standards, with a total of 5 questions. The following are the results of the validity of the mathematics questions with an open-ended approach. The validity of question number 1 (0.972), the validity of question number 2 (0.903), the validity of question number 3 (0.962), the validity of question number 4 (0.895), and the validity of question number 5 (0.697), where the five questions are greater than rtable 0.576 at a significance level of 5%, so it can be said that the five questions are valid. This shows that the five mathematics questions with an open-ended approach are able to measure what should be measured well. Field Test. At this stage, the researcher conducted a test on class IX. There were 40 students in class IX. All students worked on prototype III questions. The results of the test showed the ability of creativity in solving problems with an open-ended approach in junior high school students in Surabaya.

Table 8. Distribution of students' creative thinking skills categories in field trials (N = 40).

Category	**Field Tests**	
	Frequency	**Percentage (%)**
Very uncreative	2	5
Not creative	2	5
Quite creative	4	10
Creative	12	30
Very creative	20	50
Total	**40**	**100**

The results of the field test showed that 20 out of 40 students (50%) showed high creative abilities in answering open-ended math problems. The open-ended approach has many possible answers, encourages students to think more broadly and differently, and increases confidence in solving problems.

Here are some reasons why students become creative in solving open-ended math problems: 1) Open-ended problems encourage students to think critically and creatively. Open-ended problems do not only have one answer but rather open up space for students to explore various solutions and approaches. 2) Flexibility in problem-solving. The open-ended approach to problem solving gives students the freedom to choose strategies and methods that suit their understanding. 3) Increased self-confidence. When students succeed in creating creative solutions to open-ended problems, their self-confidence increases. This can motivate them and make them interested in mathematics. 4) Development of higher-order thinking skills such as analysis, synthesis, and evaluation. Students learn to connect concepts, identify patterns, and draw conclusions. 5) can be achieved by involving students in search and exploration, not just memorizing formulas. This can increase their interest and motivation to learn. The following is a comparison of the answers of students who answered in the categories “very creative” and “quite creative.” Pay attention to the answers in Table 9.

Table 9. Examples of Student Answers with the criteria "very creative"

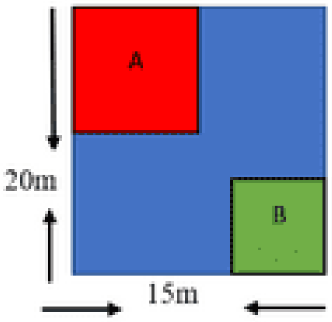
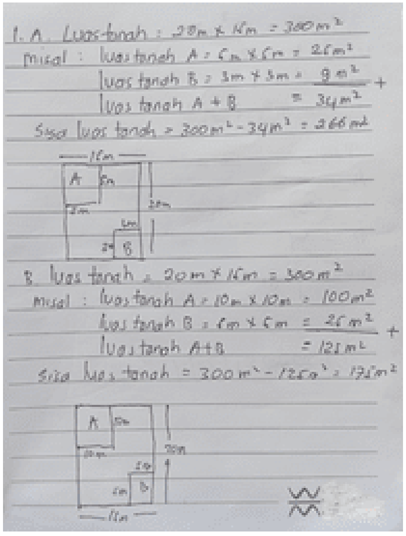
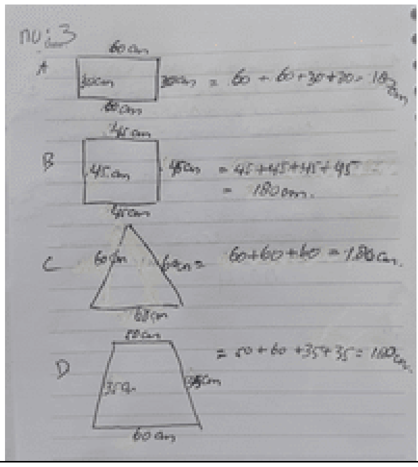
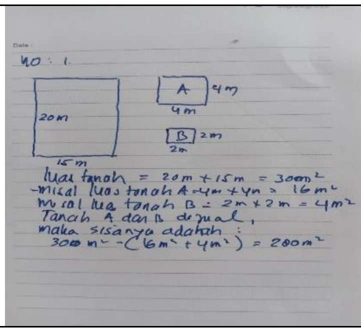
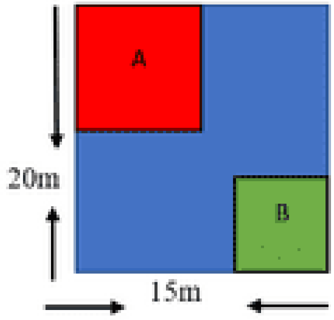
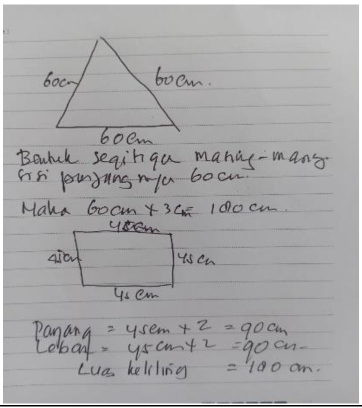
Mathematics Questions	Student Answers	Creative Criteria
Asep memiliki sebidang tanah, dengan panjang 20m dan lebar 15m, kemudian tanah A dan B telah dijual. Hitunglah luas sisa tanah Asep. Kerjakan dengan berbagai macam cara dengan benar. 		**Fluency**. Students can solve problems with more than one correct answer. **Originality** Students can identify the problems in the questions correctly and can provide the correct answers. **Flexibility.** Students can solve problems with various strategies correctly. **Elaboration.** Students can identify the problems in the questions correctly, can provide correct and detailed answers, and the results are correct.
Buatlah macam-macam bentuk bangun datar matematika yang kamu ketahui dengan keliling 180cm. Buatlah sebanyak mungkin bangun datar.		

Table 10. Examples of student answers with the criteria "quite creative"

Mathematics Questions	Student Answers	Creative Criteria
Asep memiliki sebidang tanah, dengan panjang 20m dan lebar 15m, kemudian tanah A dan B telah dijual. Hitunglah luas sisa tanah Asep. Kerjakan dengan berbagai macam cara dengan benar.		**Fluency.** One method is used to solve a problem, and the answer is correct. **Originality**. Originality is shown in the

		answer, but the answer is wrong. **Flexibility.** One strategy is used to solve the problem and the correct answer. **Elaboration** The explanation is not quite right, it is difficult to understand, but the answer is correct.
Buatlah macam-macam bentuk bangun datar matematika yang kamu ketahui dengan keliling 180cm. Buatlah sebanyak mungkin bangun datar.		

Discussion

In open-ended mathematics problems, students tend to show more prominent fluency and flexibility abilities (Ibrahim, Khalil, & Indra Prahmana, 2024). Rahayuningsih, in her research, stated that creative students are able to think flexibly when solving open-ended mathematics problems (Rahayuningsih et al., 2021). Fluency refers to the ability to generate many ideas or solutions, while flexibility refers to the ability to see problems from various perspectives and use various strategies (Sadak & Pektas, 2022). There is a relationship between fluency and flexibility in solving mathematics problems (Kurniawan, Susiswo, & Hafiizh, 2024). There is a relationship between student creativity and creative problem-solving skills (Hasret & Savaş, 2019).

The open-ended learning approach has an effect on creative thinking skills in mathematics subjects (Kartikasari, Usodo, & Riyadi, 2022). One of the learning approaches that can support students' creative thinking skills is the open-ended approach (Kartikasari et al., 2022). This is supported by research by Tanjung, which states that the open-ended approach has an effect on mathematical problem-solving skills (Tanjung, Syahputra, & Irvan, 2020). The ability to solve mathematical problems with an open-ended approach can make students participate more actively because it provides opportunities for students to develop their knowledge and abilities (Hamid, Baharom, Taha, & Kadaruddin, 2013). The open-ended approach can make students participate in learning and have the opportunity to maximize their mathematical knowledge and skills so that they can develop students' creativity (Alman, 2017).

This is also supported by the opinion that the main purpose of this open-ended approach is not only to obtain results but rather to emphasize how to achieve these results (Balan, Yuen, & Mehrtash, 2019; Mahmoud, Hashim, & Sunarso, 2020). This results in the answers given to each question being varied. The purpose of this open-ended approach is to stimulate and develop students' thinking skills in solving existing questions according to their abilities (Oliveira et al., 2021). The results of the study generally show that students with open-ended learning are better than traditional learning (Fatah, Suryadi, Sabandar, & Turmudi, 2016).

The open-ended learning approach is a learning process that offers a learning process that begins with the provision of problems related to the concept to be discussed (Hafidzah, Azis, & Irvan, 2021). Students can develop various abilities by how they solve a problem in various ways according to their abilities, both from knowledge and experience (Chang & Lan, 2021; Rizos & Gkrekas, 2023). Mathematics often presents a problem that must be solved by students. So that students are required to be able to solve these problems well (Stojanović et al., 2021). Learning techniques with an open-ended approach can improve children's mathematical abilities while contributing to their general cognitive development (Warmansyah et al., 2023). This open-ended mathematics learning approach makes students not only find results but also argue in explaining the process to achieve these results (Hassan, Rosli, & Zakaria, 2016). In the learning process using this open-ended approach, students practice solving problems, expressing opinions, and explaining how to solve problems in their way (Shafie, Shahdan, & Liew, 2010).

Research that can strengthen the results of this study states that the right learning approach is fundamental, which can later help students in solving mathematical problems (Fauzi, Usodo, & Subanti, 2017). Other studies state that students' mathematical representation of visual reality is higher than the descriptive form (Kowiyah & Mulyawati, 2018). Other research findings also state that the open-ended approach is practical in learning (Hamid et al., 2013; Oliveira et al., 2021). It can be concluded that the open-ended approach is suitable for use in the learning process.

The implications of the analysis of the results of this study are that students tend to provide many answers that show fluency and flexibility but lack in providing unique answers (originality) and the ability to develop detailed answers (elaboration). Therefore, teachers who want to use similar questions are advised to place more emphasis on instructions to find “unusual ways” or “different solutions from friends.”

The limitations of this study are as follows: 1) Generation. The research sample is limited to several schools in Surabaya, so the results cannot be generalized to the entire student population in Indonesia. 2) Consequential Validity. This study has shown content and construct validity, but its impact on the learning process and student motivation in the long term has not been tested. 3) Number of respondents. The sample size of 40 students from a population of 110 students may be less representative of describing the condition of the entire population. Ideally, for a population of 110, it is advisable to take a larger sample so that the research results are more accurate and can be generalized to all students. 4) Reliability. The use of only Cronbach's alpha reliability in this study does not take into account inter-rater reliability. Thus, leaving subjectivity in the assessment of creativity.

▪ CONCLUSION

This study produced a valid and reliable assessment instrument; this study provides a concrete tool for educators and researchers to overcome the challenges in measuring and ultimately fostering mathematical creative thinking skills, a crucial competency that is reported to be still low at the national level. The results of the product development are in the form of open-ended mathematics questions that are valid, reliable, and have good question characteristics. Based on the results of small group trials and field tests of students in solving open-ended questions, it was found that students' creative thinking skills in problem solving, as seen from the diversity of solutions, showed an average creative thinking ability; this means that in open-ended questions, especially on two-dimensional plane geometry topic, students are in the fluency, originality, flexibility, and elaboration abilities. Suggestions for further research: 1) testing this instrument on a larger scale with a more diverse sample to test the stability of its psychometric properties; 2) conducting comparative studies to see how different question designs (for example, questions with real-world contexts versus pure mathematical questions) affect different aspects of creativity; and 3) developing a training program for teachers on how to assess open-ended questions using a validated rubric consistently.

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