

Development of Open-Ended Based Mathematics Problem to Measure High-Level Thinking Ability

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Abstract. The study aims to produce Open-Ended based mathematics problems that can be used to measure the high-level thinking abilities of seventh-grade junior high schools' students. The study is developmental research using Plomp model, consisting of the preliminary stage, the prototyping stage, and the assessment phase. The subject was seventh-grade students of junior high school. The teaching material used was about numbers learned at seventh-grade junior high school. Based on the results of the development, it was obtained 15 open-ended based problems in which 12 of them possibly have various answers, and 3 have various possibilities ways of answering. The problems developed are valid with the criteria of the developed problem based on content, the problems have diverse answers or various ways to answer, problems can measure high-level thinking skills; analyzing, evaluating, and creating, and the content of the material is fit to the material about numbers. The problems use clear construct images, clear instructions for working on, adapted Standard Indonesian Spelling System or EYD language, and appropriate sentences to seventh-grade knowledge level, disuse of misinterpreted expressions as well. Related to practicality, it is obtained that students and teachers can use the problem and do it well. The teacher can use it to evaluate students' high-order thinking skills.

1. Introduction

Thinking skills can be divided into two levels, high-level thinking skills or Higher Order Thinking Skills (HOTS) and low-level thinking skills or Lower Order Thinking Skill (LOTS). High-level thinking ability or HOTS is very important for every student. HOTS is a term that is increasingly being referred to in the 21st-century education era because it is considered as one of the 21st-century skills. HOTS is a skill that includes a person's ability to think critically, logically, reflectively, metacognitively, and creatively [1,2]. These competencies need to be given in order that students have the ability to obtain, manage and utilize information to live better in continuously changing, uncertain and very competitive situations [1]. One of the efforts that can be done to have students with HOTS ability is to get used to working on high-level problems such as questions that direct students to analyze, evaluate, and create. Some research also suggested that teachers use high-level thinking skills questions and solve problems with various strategies (Open-Ended) [3,4].

Open-Ended Problems are questions that have more than one solution, or more than one answer. This means that Open-Ended problems are questions with an open category. It needs to be given in school learning so that mathematics can be more preferable and learned by all students, then close-ended problems should be replaced with open-ended problems Shimada [5] states that the open-ended approach begins with a view on how to objectively evaluate students' abilities and high-level



mathematical thinking. By giving open-ended problems can improve mathematical creative thinking skills which are also included in the High Order Thinking Skills (HOTS) [6,7].

However, Shadiq [8] said that the characteristics of learning mathematics at this time were more focused on procedural abilities, one-way communication, low order thinking skills, and more dominant on routine questions and low-level problems. Based on the results of the analysis carried out on several teaching materials used by the teacher or the students, there have already been several high-level ability questions such as problem-solving, or critical thinking, but the questions are still more dominant in closed-ended problems. The sample footage contained in the teaching material is as seen in figure 1 and 2.

Suatu gedung tersusun atas 5 lantai. Jika tinggi satu lantai gedung adalah 6 meter, tentukan tinggi gedung tersebut (tanpa atap).



Translation:

A building consists of 5 floors. If the height of each floor is 6m, then determine the overall height of the building (without roof).

Figure 1. Snapshot of the Problem in Numbers Material

In Figure 1 the questions given are still closed-ended problems. Students only need to do a 5×6 multiplication because the number of bases and the height of one base is known.

3. Suppose the symbol " b " represents a number, specify the number b so that the number $63b452$ is less than 635452 . Explain your answer.
4. Suppose the symbol " c " represents a number, specify the number c so that the number $c45279$ is less than 635452 . Explain your answer.

Figure 2. Snapshot of the *Open-Ended* Problem in Numbers Material

Whereas in Figure 2 it is included in the open question or based on Open-Ended. For example, in question number 3 there are several possible answers that can be given by students namely "634452", "633452", "632452", "631452", or "630452". In some of the Student Worksheets they use, surprisingly there are not open-ended questions or questions that can hone students' high-level thinking skills (HOTS). It needs to be added and supplemented with Open-Ended problems that can be one of the ways to improve students' high-level thinking skills and teach students to be creative as needed by today's society.

2. Method

The development model used in this study is the model developed by Tjeerd Plomp. The Plomp model consists of three phases (Plomp and Nieveen, 2013), namely (1) preliminary research with context needs analysis activities, literature review, conceptual development and theoretical frameworks for research. (2) the planning stage (prototyping stage) where this stage uses formative evaluation adopted from the Tesmer, and (3) The assessment stage (assessment phase), which is the semi-summative evaluation phase to conclude the results of the development. [9]. The flow of formative evaluation design is as seen in figure 3.

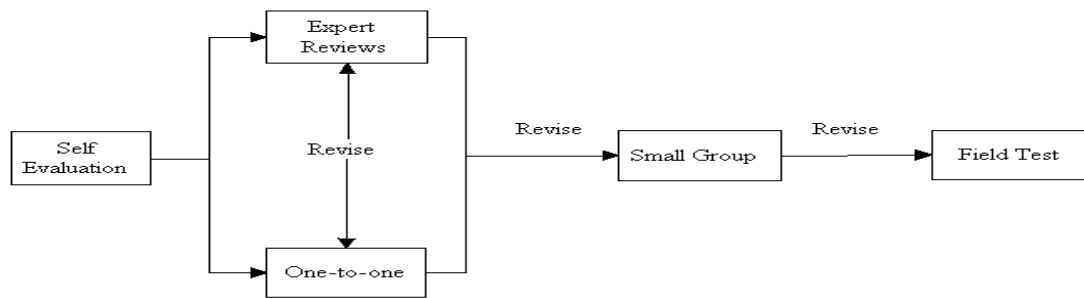


Figure 3. The flow of Formative Evaluation Design

The trial subjects of this study were the seventh-grade students of 1 Junior High School Bangkinang, and 2 Junior High School Bangkinang. Data collection techniques at the stage of data analysis are in the form of interviews, and documentation, at the prototyping stage, is in the form of documentation interviews, questionnaires, and at the assessment, stage is in the form of tests that are open-ended based questions to measure High Order Thinking Skills (HOTS). There are various opinions related to the HOTS indicator, but in this study, the HOTS indicators used to refer to Bloom revisions. According to Liu, the component of HOTS is analyzing, evaluating, and creating as contained in Revised Bloom's Taxonomy [10].

3. Result and Discussion

3.1. Result

3.1.1. Need Analysis

At the stage of the need analysis, information is collected regarding the problem of the available evaluation tools. Based on interviews conducted on several teachers, information was obtained that the teacher usually only made routine questions or closed-ended problems because the teacher never developed an open-ended question or open-ended based. The questions commonly used by teachers for evaluation are only routine questions, or only up to applying mathematical formulars, which question is only up to the stage of applying or application or C3 on the revised Bloom's taxonomy. Based on the analysis conducted on teaching materials such as books that hold students, there have already been several open-ended problems, such as the following snippet.

Based on Figure 2, question number 4 is an *Open-ended* question which has more than one possible answer, namely "145279", "24579", "345279", "445279", or "545279". On the question, there was also an error in writing the letter that was asked, namely "c". The available open-ended based questions still need to be added. It needs to be done so that the teacher has no difficulty in getting open-ended questions that are very beneficial for the development of students. Furthermore, the results of worksheets analysis commonly used by students did not have even any open-ended based questions. The available questions are only routine and closed-ended problems. Through several data collection techniques, it is concluded that it is necessary to develop *Open-ended* based questions for evaluation tools and sharpen the skills of students. The questions also aim to measure students' high-order thinking skills, the ability to analyze, evaluate, and create.

3.1.2. Students Characteristics Analysis

Mahmudi said that every student has different characteristics related to problem-solving activities [11]. There is someone who often uses informal methods to solve problems rather than using formal methods or procedures. There are characteristics of students who prefer to be alone in solving problems given, there are students who like to answer problems based on examples given by previous teachers, there are students who like to solve problems with one procedure, and there are students who like to be creative in solving problems given. Therefore, mathematics needs to be designed so that it

can accommodate a variety of characteristics of students. Mahmudi stated that one way that can be done is by the use of open-ended problems in mathematics learning [11]. Open-ended problems can be a solution related to various characteristics possessed by students.

3.1.3. Curriculum Analysis

Curriculum analysis is carried out on material about numbers in the 2013 curriculum. Based on Figure 4, there are three basic competencies and each has two, or three indicators. In this study, the basic competencies to be developed are KD 3.1 and 3.2.

3. Kompetensi Dasar dan Indikator Pencapaian Kompetensi (IPK)	
Kompetensi Dasar (KD)	Indikator Pencapaian Kompetensi (IPK)
3.1 Menjelaskan dan menentukan urutan pada bilangan bulat (positif dan negatif) dan pecahan (biasa, campuran, desimal, persen)	3.1.1 Menjelaskan urutan pada bilangan bulat (positif dan negatif) dan pecahan (biasa, campuran, desimal, persen) 3.1.2 Menentukan urutan pada bilangan bulat (positif dan negatif) dan pecahan (biasa, campuran, desimal, persen)
3.2 Menjelaskan dan melakukan operasi hitung bilangan bulat dan pecahan dengan memanfaatkan berbagai sifat operasi	3.2.1 Menjelaskan berbagai sifat operasi hitung yang melibatkan bilangan bulat dan pecahan 3.2.2 Menentukan operasi hitung bilangan bulat dan pecahan dengan memanfaatkan berbagai sifat operasi.
3.3 Menjelaskan dan menentukan representasi bilangan bulat besar sebagai bilangan berpangkat bulat positif	3.3.1 Menjelaskan konsep bilangan bulat berpangkat 3.3.2 Menjelaskan notasi penulisan bilangan bulat besar sebagai bilangan berpangkat bulat positif 3.3.3 Menentukan perbandingan bilangan berpangkat besar

Figure 4. Footage of Basic Competencies and Indicators of Achievement of Competence

3.1.4. Prototyping Phase

Question development is based on open-ended criteria that can familiarize and measure students' high-order thinking skills. Open-ended based mathematical questions are designed based on the results of the preliminary analysis that has been done. Besides, the questions developed were also designed by considering the results of the students' characteristics analysis. The questions developed are 15 questions which refer to the indicators specified. Examples of questions developed.

Question 1

The first question developed based on indicator 3.1.2 determines the sequence of integers (positive and negative) and fractions (ordinary, mixed, decimal, percent). The form of the question is as shown in figure 5.

1. Isilah titik-titik di bawah ini dengan menuliskan bilangan rasional!



Translation:

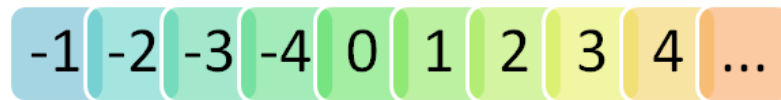
1. Fill in the spaces below with rational number.

Figure 5. Question Number 1

Question 2

Question number 2 is a question that refers to indicator 3.1.1 explaining the sequence of integers (positive and negative) and fractions (normal, mixed, decimal, percent). The sample snippets are as shown in figure 6.

2. Apakah bilangan di bawah ini merupakan urutan bilangan bulat yang tepat? Jelaskan



Translation:

2. Is all number below are in the right order? Explain your answer.

Figure 6. Question Number 2

In Figure 6. Students can provide various possible answers. Suppose that the students will answer "Incorrect, because the sequence before 0 should be $-1, -2, -3, dan -4$ " or, a Not right, the correct answer is $-4, -3, -2, -1, 0, 1, 2, 3, 4, \dots$ ", or" incorrect, because the correct answer is $-4 < -3 < -2 < -1 < 0$. According to what was conveyed by Mahmudi that closed-ended questions can be changed into open-ended questions like the following example [11].

3.1.5. Self-Evaluation

At this stage, researchers conduct their own evaluations based on validity criteria, and practicality. Based on the results of the evaluation, there are improvements, namely the typing of words. Based on the results of Self Evaluation, it was obtained the first prototype consisting of 15 Open-Ended based questions.

3.1.6. Expert Review

The first prototype obtained after Self-Evaluation was given to experts in the field of mathematics education consisting of 2 people, and one-person language expert. Based on the results of the revision, there are several questions that need to be corrected based on expert advice. Footage of repairs provided by experts are as follows.

Table 1. Results of Expert Validation

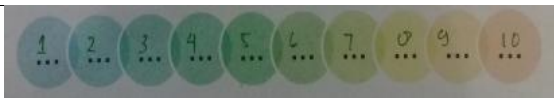

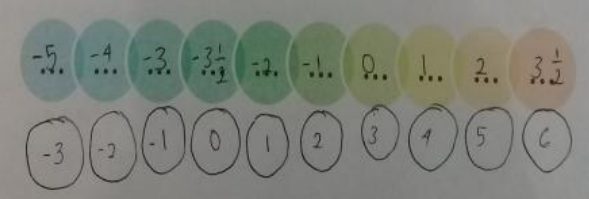
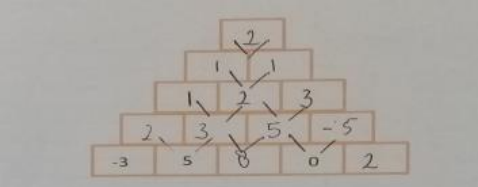
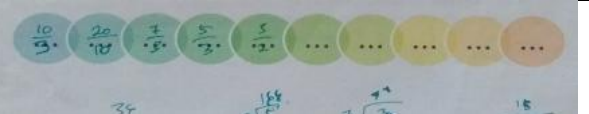

Review	After Revision
<p>Isilah titik-titik di bawah ini dengan menuliskan bilangan rasional!</p>	<p>Isilah titik-titik di bawah ini dengan menuliskan urutan bilangan rasional!</p>

Based on reviews from experts, improvements were made to the words used as shown in Table 1 number 1 and 2. Based on the results of the review and revision, prototype 2 was obtained.

3.1.7. One-to-One

The result of expert review, prototype 2, was then conducted to a one-to-one test which involved three students with high, medium, and low abilities. The three people are students who have studied material about numbers. The students were given open-ended based questions that had gone through the validation process. Then the three students were also interviewed about the matter of the number material. The answers of the three students were then analyzed regarding their validity. The following are snippets of answers from students.

Table 2. Student's Answer

No	Nomor 1	Nomor 4
1		
2		
3		

In Table 2 number 1 was the answer of high-ability student, number 2 was the answer of student with moderate ability, and number 3 was the answer of low-ability students. Based on the analysis of item validity and the results of students' interviews, prototype 2 was revised and based on the improvements, prototype 3 was produced.

3.1.8. Small Group

Based on the results of one-to-one revision, prototype 3, a small group trial (Small Group) was conducted to 6 students representing three level abilities, high, medium and low. The students were asked to complete the designed open-ended based questions. The students were also given questionnaires and interviews regarding to the questions. Besides, the questions were also used and analyzed by mathematics teachers relating to the practicality of using the developed open-ended questions.

3.1.9. Field Test

The result of prototype 4 that has been produced was tested to the research subjects, in this case, is SMPN 2 Bangkinang City. The aspect that was considered in this Field Test was the effectiveness of the open-ended based questions developed. Open-ended questions that are developed based on aspects of the revised taxonomy, analyzing, evaluating, and creating.

3.2. Discussion

3.2.1. The Prototype of The Valid and Practical Open-Ended Questions

Through the development processes consisting of three stages, Self-Evaluation, Expert Review, and One-to-One, there were 15 open-ended based questions on the subject of numbers for basic competencies (KD) 3.1 Explain and determine the sequence of integers (positive and negative) and fractions (ordinary, mixed, decimal, percent) and 3.2 explain and perform integer and fraction count operations by utilizing various operating properties. The open-ended based questions consist of 12 questions that have several possible answers and 3 questions that have several possible ways to answer. The validity of open-ended questions was obtained from the validator's assessment and the one-to-one test. Open-ended questions are considered to be good to the open-ended based criteria generated based on the content, constructs, and languages in which the indicators are listed in Table 3.

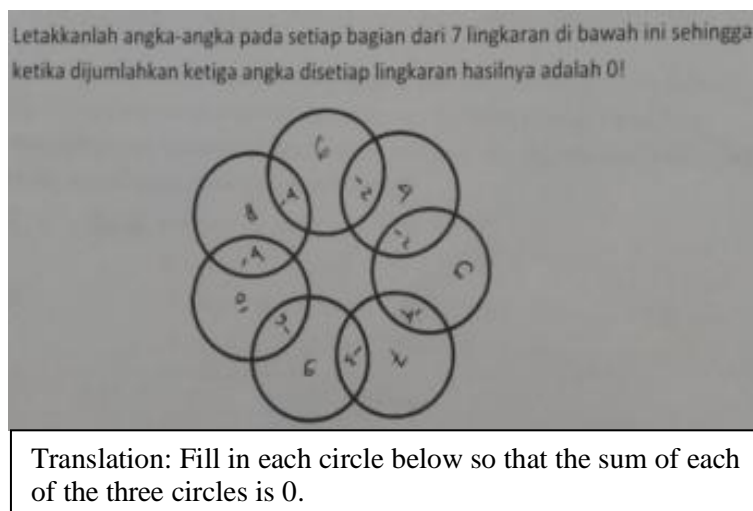
Table 3. Aspects of Validity Questions

Evaluation Components	Indicators
Content	1. The developed questions have various answer or various ways of answering.
	2. The questions can measure the high-level thinking ability; analysing, evaluating, and creating (Revised Bloom C3 to C6)
	3. The content of tested material is fit to the type and level of education, VII Grade students.
	4. The questions are contextually related to students' daily life or students can imagine.
Construct	1. The figures used on the questions are clear.
	2. There is a clear instruction how to complete the questions.
Language	1. The items of questions use sentences adapted by EYD.
	2. The questions match to the students' knowledge level.
	3. It does not use ambiguous expression

The practicality of open-ended questions is seen from the results of observations on the small group trial. Based on the analysis conducted, it was found that the questions developed were easy to use by students and teachers, easy to read, and could be used by students.

3.2.2. Assessment Phase

Prototype 4 which has been valid and practical based on the Field Test results shows that all aspects of the development of open-ended based questions can measure and influence the level of high-level thinking ability of students. Based on the analysis of the students' answers, it can be seen that if students are given open-ended questions, students are able to develop ideas they have to solve the problem given.

**Figure 7.** Footage of Student's Answers

4. Conclusion

Based on the results of the development stages carried out starting from self-evaluation to field tests it was obtained 15 open-ended questions which are valid with the criteria of the questions developed based on content ; questions have diverse answers or various ways of answering, questions can measure high-level thinking skills such as analyzing, evaluating, and creating, and the content of material was fit to material about number. Related to the construct image used in the question is clear, and there are clear instructions to do and having a language adapted to EYD, the sentence matches the level of knowledge of grade VII junior high school students and does not use expressions that cause interpretation. Related to practicality, it is obtained that students and teachers can use the question and

do it well. The teacher can use it to evaluate students' high-level thinking skills because open-ended questions can teach students to analyze, evaluate, and create.

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