

# Development of Higher Order Thinking Skills (HOTS) Test Instruments in Geometry

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## ABSTRACT

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Critical thinking, creativity, communication, and collaboration are all skills that students must have in the twenty-first century. A meaningful assessment, where the assessment can develop higher-order thinking skills, is one effort to realize the achievement of 21st-century skills. The goal of this research is to develop a HOTS test instrument relying on valid and reliable geometry for students. This study is a development study that employs the Akker development model. This study's data was gathered through questionnaires, documentation, interviews, and tests. The data were descriptively, qualitatively, and quantitatively analyzed. As a result of this research, the HOTS test instrument on the developed material is valid and reliable for students. The results of the expert's assessment of the content and language of the questions indicate the validity of the questions. The overall validity of the test instrument is 85.71 percent. A large-scale trial involving 110 students in grade 10 of senior high school yielded the empirical validity and reliability of the test items, with the test results indicating that 18 items were declared valid and reliable. As a result, the created Geometry test instrument can be used to assess students' HOTS abilities.



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## A. INTRODUCTION

The world is currently undergoing rapid development and change in many areas of life. These changes occur as a result of advancements in information, automation, globalization, and digital technology (Gravemeijer et al., 2017). To be able to deal with these changes, students must have the necessary skills for this century and the future. These abilities are referred to as 21<sup>st</sup>-century skills, and they include critical thinking abilities, creativity, communication, and collaboration (Kim & Md-Ali, 2017).

Furthermore, three things must be done in order for students to achieve 21<sup>st</sup>-century skills. The first is an adaptive curriculum; the second is a learning model that can develop collaborative, interactive, creative, and innovative abilities; and the third is a meaningful assessment, specifically one that can develop higher-order thinking skills, abbreviated as HOTS. The Indonesian government stated these three points in the revised 2013 curriculum, which is used as a learning guide (Kristanto & Setiawan, 2020).

Resnick has been conducting HOTS research since 1987 (Yurniwati & Utomo, 2020). According to Brookhart (Wena, 2020), higher order thinking skills (HOTS) are a transfer

process (the ability of students to apply what they have learned into new situations without direction or guidance from educators or other people). HOTS stands for critical thinking (forming students who can think logically, reflectively, and make decisions independently. HOTS-based assessment includes the three highest Bloom's Taxonomy assessments, namely C4-analysis, C5-evaluation, and C6-creation. According to (Arter & Salmon, 1987), the HOTS abilities are as follows: (1) problem solving; (2) decision making; (3) drawing conclusions; (4) divergent thinking; and (5) the ability to evaluate.

HOTS is one aspect of being able to think creatively and critically. When students can use these two skills, it means they have mastered higher-order thinking skills. Every student can think, but the majority of them require encouragement, instruction, and assistance in higher-order thinking processes (Heong et al., 2011). This ability will develop when a person encounters unusual problems, conditions, or phenomena that they have never seen before.

Geometry is a branch of mathematics that students study from elementary school to college. Geometry is a unique mathematical concept with a level of complexity, according to Jones and Al (Yurniwati & Utomo, 2020), because solving problems in Geometry involves physical activity (such as using various tools/instruments, manipulating and modelling), visualization and language.

Geometry teaching and learning benefits students in their everyday lives because it is related to creativity, problem-solving, spatial understanding, and shape (Gagatsis, 2021). According to this (Siregar & Siregar, 2020), geometry learning generally aims to: (1) increase confidence and think logically; (2) be able to solve problems; (3) improve spatial intuition; (4) improve reasoning; (5) critical thinking; and (6) boost students' creativity. Based on the foregoing, it is possible to conclude that Geometry learning can also improve students' HOTS abilities.

These learning objectives, however, are not easily attained. Students' HOTS ability, particularly in Geometry, remains low. This is evidenced by students' poor performance in the Geometry domain in international mathematics assessments such as PISA and TIMSS (Kim & Md-Ali, 2017). Many students struggle to answer HOTS questions for this material (Muslim et al., 2018). Furthermore, the preliminary study conducted by the researchers revealed that the average ability of students for 30 research subjects for the reasoning ability on the topic of geometry, the topic of cube and cuboid construction was 47.08 in the low category.

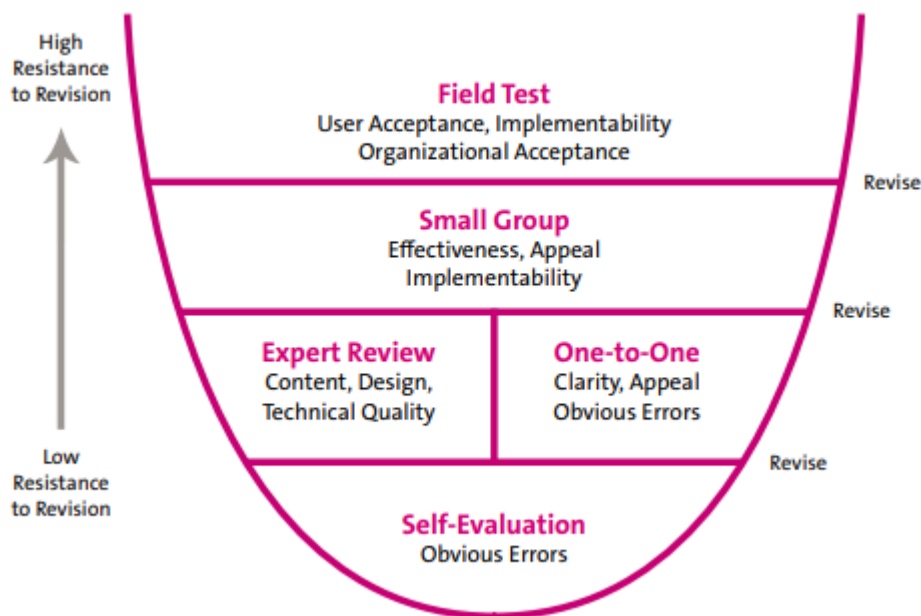
One of the reasons in that the current learning and assessment system is still limited to low cognitive levels (Lower Order Thinking Skills) and moderate cognitive levels (Medium Order Thinking Skills), such as the ability to remember, understand, and apply (Widana, 2018). According to (Cesaria & Herman, 2019) the teacher's Geometry learning method is not yet appropriate. Furthermore, the low ability of HOTS is due to the fact that they have not been trained to answer HOTS questions (Marlina et al., 2019).

As a result, researchers are eager to create and refine a HOTS test instrument of Geometry. This test instruments is designed to allow students to practice their HOTS skills. Previous researchers, namely (Marlina et al., 2019) were responsible for the development is restricted to the secondary school level (Antara et al., 2020). Also worked on the development of the HOTS test on Flat-plane geometry for the Elementary School level. Although the HOTS test instrument has been widely developed, there has never been a joint development of the HOTS

test instrument for Geometry at the junior high and high school levels. The goal of this research is to develop a HOTS test instrument Geometry relying on valid and reliable for students.

**B. METHODS**

The development research method was used in this study, along with the Akker development model. The subjects of this study were 110 grade X high school students from several schools, including SMA Negeri 3 Palembang, Madrasah Aliyah Negeri (MAN) 3 Palembang, and SMA Negeri 6 Prabumulih. The material developed in making HOTS questions in this study is geometry material about similarity and congruence, building flat side spaces and curved side spaces, triangles and quadrilateral, as well as lines and angles. According to Tessmer (Gravemeijer & Cobb, 2013), the stages of development include a preliminary study and a formative evaluation stage. The preliminary stage consists of analysis and design, whereas the design flow in the formative evaluation stage is depicted as shown in Figure 1.



**Figure 1.** Formative evaluation stage

This study’s data collection methods included questionnaires, interviews, documentation, and tests. The questionnaire contains a series of questions designed to assess the feasibility of the HOTS test instrument on geometric material created by the researcher. The questionnaire is in the form of a checklist, and the respondent only needs to put a tick (√) in the appropriate space. The questionnaire contains approximately 20 questions with positive and negative statements. Interviews were conducted to gather additional information at each stage of the research. Documentation in this study refers to data collected during the research process, such as documents or photos, that researchers can use to analyze data and facilitate research, whereas tests are used to assess student’s HOTS abilities on Geometry. The HOTS indicators used in this study are: (1) analyze/C4 (analyze incoming information and divide or structure the information into smaller ones to identify patterns or relationships, able to recognize and distinguish the causes and effects of a complex scenario, identify or formulate questions); (2)

evaluate/C5 (provide an assessment of solutions, ideas and methodologies using suitable criteria or existing standards to ensure their effectiveness and benefits, hypotheses, critique and test, accept or reject a statement based on predetermined criteria); and (3) Create/C6 (generalize an idea or point of view on something, design a way to solve the problem, organize elements or become new structures that have never existed before) (Nursalam, 2019).

To obtain the HOTS instrument that met the valid and reliable criteria, data analysis was performed. There were 7 experts involved as validators in this study, 3 lecturers and 4 teachers. 1 lecturer in mathematics education from Universitas Islam Negeri Raden Fatah Palembang, 2 lecturers in mathematics education from Universitas Muhammadiyah Palembang. 2 junior high school mathematics teachers in Palembang, 1 junior high school mathematics teacher in Central Bangka, and 1 senior high school mathematics teacher in Lampung. Validation data for expert evaluation of the prototype, using the assessment criteria from Meltzer (Pujiastuti et al., 2020) listed as shown in Table 1.

**Table 1.** Criteria of validity

Interval score	Criteria
< 21%	Very not valid
21 - 40 %	Not valid
41 - 60 %	Enough valid
61 - 80 %	Valid
81 - 100 %	Very Valid

The empirical validity of the HOTS Geometry test questions was determined during the field test stage. Pramana, et al stated that the product moment correlation formula was used to test the validity of the test questions, as follows (Pramana dkk, 2015): If the value of  $r$  count  $>$   $r$  table, the question is declared valid. The Alpha Cronbach formula is used by the researcher to determine the level of reliability of the HOTS test instrument on the developed geometry material. If the value of  $r$  count  $>$   $r$  table, the question is declared reliable. At the field test stage, the students' HOTS ability can be determined based on the HOTS test.

### C. RESULT AND DISCUSSION

This question is developed through two major stages of development study: preliminary study (preparation stage and design stage) and formative evaluation (evaluation self, expert reviews, one to one, and small group), and field test. Preliminary study activities include research preparation, specifically the analysis and design of the HOTS Geometry test instrument. The analysis stage is used to determine the fundamental competencies that will be used in the creation of test instruments. At this point in the analysis, the geometry material used in this study is limited to junior high school (SMP) geometry material. Because of the material's high level of complexity, students must be able to use and develop higher-order thinking skills (HOTS) (Yurniwati & Utomo, 2020).

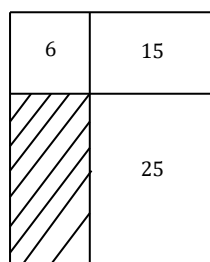
Researchers were successful in compiling HOTS questions for Geometry for Junior High School (SMP) level during the design stage. In this study, the HOTS question indicators are restricted to the C4 (analysis) and C5 (evaluation) levels. This is consistent with Brookhart's statement (Wena, 2020) that the HOTS-based assessment includes the three highest Bloom's

Taxonomy assessments, namely C4-analysis, C5-evaluation, and C6-creation. The design of the questions created consists of 23HOTS Geometry test questions.

The researcher used a formative evaluation design developed by Tessmer during the formative evaluation stage (Qirom et al., 2020). The validation process, which is carried out at the expert reviews and one-to-one stages, qualitatively reviews the accuracy of the content and language used in the questions. Several change have been made to the question sentence in response to the validator’s comments. Figures 2 and 3 show examples of revisions that have been made.

**Before Revision**

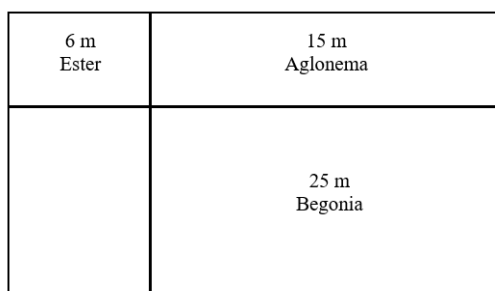
A rectangle is divided into four smaller rectangles. The areas of the three small rectangles are 6, 15, 25 respectively. What is the area of the shaded area?, as shown in Figure 2.



**Figure 2.** Before the revision of test number 5

**After Revision**

A rectangular garden will be planted with four different types of plants. If the area of the garden to be planted with Esther, Aglonema, and Begonia flowers is 6 m, 15 m and 25 m, respectively, as shown in the picture below. Determine the area of the park that is still vacant?, as shown in Figure 3.



**Figure 3.** After the revision of test number 5

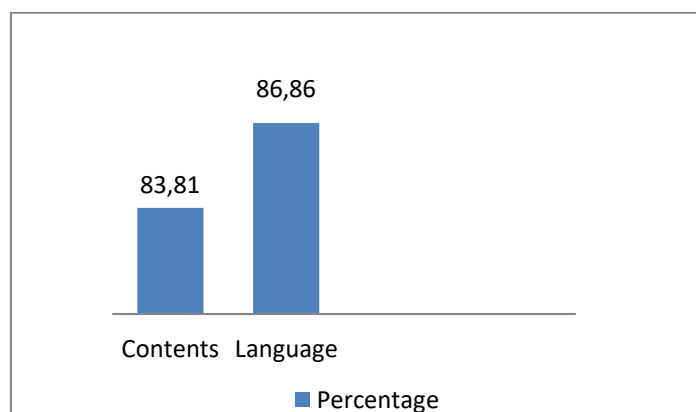
**Before Revision:**

There is a photo affixed to a rectangular cardboard. The photo is 10 cm × 25 cm and the width of the right, left and top is 2 cm. If the photo and the cardboard are congruent then determine the width of the bottom cardboard.

**After Revision:**

A photograph affixed to a rectangular cardboard. The photo is 10 cm ling and 25 cm wide. The photo distance from the top, right, and left edges of the cardboard is 2 cm. Photo and cardboard are congruent. If Ahmad stated that the distance of the photo from the bottom edge of the cardboard is 5 cm, what do you think, explain!

Figure 3 show the difference in question sentences before and after expert review validation. When the expert suggested in item number 5 that the questions be related to everyday life, the scale of the picture is also not quite right. As a result, the researcher revised the question sentences by relating them to everyday life and snapping pictures them at the appropriate scale. Furthermore, the experts stated that the sixes of the photo and the distance of the photo on the cardboard was unclear for item number 15, and that the question sentence was still ambiguous, so it had to be corrected. As a result, the researcher improved the sentence questions based on expert advice. The expert evaluates the test instrument for content and language after it has been revised. Figure 3 depicts the results of the validator's evaluation of the second prototype, as shown in Figure 4.



**Figure 4.** The results of the validator's evaluation

The total percentage obtained is 85.71 percent, with a very valid category, based on the validator's assessment. As a result, it is possible to conclude that the second prototype is ready for further testing. The second prototype developed from the previous two stage was tested on 17 10<sup>th</sup> grade students at a Palembang high school. On October 13, 2021, a small group activity will be held. Students are given questions in pdf format, and their answers are entered into a Google form. In addition, students' responses are documented for analysis and re-evaluation.

After working on the second prototype question, the researcher conducted a written interview to learn about the students' difficulties. Interviews pertaining to difficult questions and the reasons for these difficulties. A Google form is also used to provide interview sheets. At this stage, the results of the interviews are also used to revise the HOTS Geometry test. The result can be seen in Table 2.

**Table 2.** Students' comment on Small Group phase

Date	Commentator	Comments and suggestions
13 October 2021	AMM	Question no 5 and 7 are difficult
13 October 2021	AC	Question no 7, 16, 19 and 20. Questions should be made less burdensome and more understandable.
13 October 2021	NN	Questions no 7, 18, and 20. Confusing questions

Students' comments and suggestions during the small group stage are critical information for researchers as they revise the second prototype. Some questions are not understandable or confusing, according to student suggestions and comments. As a result, the researchers re-

checked and revised some on these question. The examination of returned questions yielded the following results: question no. 7 pictures of unclear questions, and question no. 20 sentence questions are still ambiguous. The two questions were removed from the test instrument after only a few revisions. As a result, the second prototype question, which had 20 questions, was reduced to 18 questions. The results of this revision are known as third prototype, and they will be tested on large groups of students (field test).

The field test stage was carried out to empirically assess the validity and reliability of the questions. This field test stage was held on October 18, 2021, and involved 110 10<sup>th</sup>-grade students from the city of Palembang. The method for carrying out this field test is similar to that of a small group activity. Following the collection of student responses, an analysis of the validity and reliability of the HOTS Geometry test questions is performed, yielding the following results:

### 1. Validity Test Outcomes

Researchers examined students' responses to Geometry HOTS test question. Item validity is calculated by determining the product-moment correlation form Karl Pearson. The SPSS 22 application is used to calculate the validity of these items. The results of the SPSS output, the validity test result can be seen in Table 3.

**Table 3.** The Result of Validity Test

Question Item Number	$r_{xy}$	$r_{table}$	Description
1	0,493	0,1891	Valid
2	0,623	0,1891	Valid
3	0,697	0,1891	Valid
4	0,633	0,1891	Valid
5	0,669	0,1891	Valid
6	0,546	0,1891	Valid
7	0,599	0,1891	Valid
8	0,613	0,1891	Valid
9	0,647	0,1891	Valid
10	0,533	0,1891	Valid
11	0,687	0,1891	Valid
12	0,486	0,1891	Valid
13	0,482	0,1891	Valid
14	0,519	0,1891	Valid
15	0,545	0,1891	Valid
16	0,646	0,1891	Valid
17	0,508	0,1891	Valid
18	0,554	0,1891	Valid

The results of these calculations show that there are 18 valid questions.

### 2. The Results of the Reliability Test

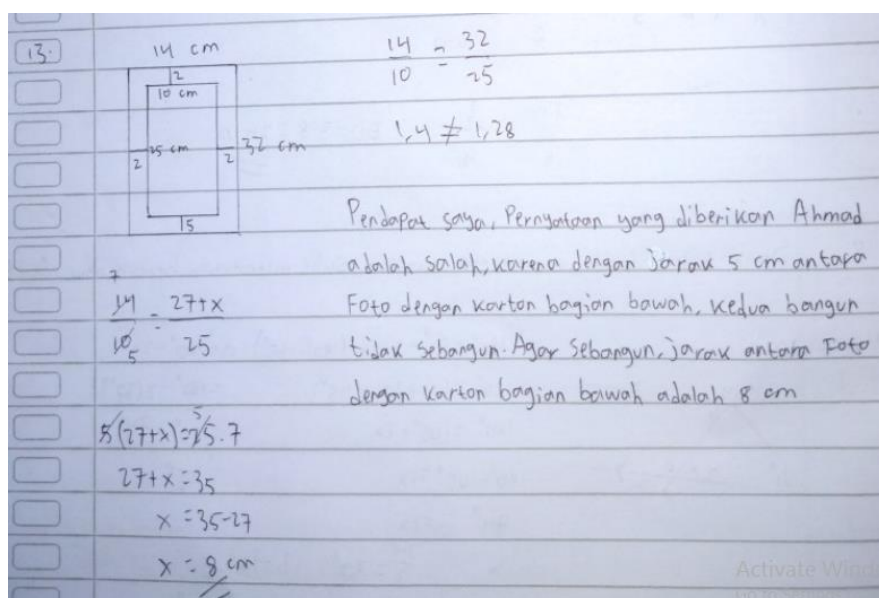
Furthermore, the researcher employs the Alpha Cronbach formula to assess the level of dependability of the HOTS instruments on the developed geometry material. The SPSS 22 application is also used to calculate reliability. The reliability test result can be seen in Table 4.

**Table 4.** The Result of Reliability Test

Cronbach's Alpha	N of Items
.882	18

According to Table 4. The calculated  $r$  value is 0.882, while the  $r$  table value is 0.468. As a result, if  $r$  arithmetic  $>$   $r$  table, the 18 questions produced are considered as reliable. Another finding in this study is that students struggle with HOTS Geometry questions. According to data analysis, as many as 1 student has very high HOTS ability, 5 people have high ability, 9 people have moderate ability, 37 people have less ability, and 58 students have very high HOTS ability, accounting for 52.73 percent of students. Unsatisfactory the proportion of students with low HOTS abilities is consistent with (Muslim, M. Ikhsan, & Abidin, 2018).

Following further investigation, it was determined that the student's difficulty is in question number 13. Students must be able to understand and explain the concept of rectangular congruence in order to answer this question. The majority of the students were unable to explain the concept. Students with a high level of ability, on the other hand, can explain but are less thorough in using algebra. Figure 5 shows an example of an answer to question number 13, as shown in Figure 5.

**Figure 5.** Students' worksheet for questions no. 13

#### D. CONCLUSION AND SUGGESTIONS

According to the study's findings, the HOTS instrument's characteristics on valid and reliable geometry material were as follows: (1) The validity of the test instrument (question) was determined by expert who evaluated the questions based on their content and language. A prototype set of 23 questions was created, with the content aspect aligned with the HOTS indicator. In terms of language, the questions developed have used standard language that is consistent with the EYD, the instructions and directions used are clear, the command sentences are easy to understand, and there are no ambiguous sentences (causing multiple interpretations). (2) The results of the field test activities show the empirical validity and reliability of the questions. The results of the test show that the 18 HOTS items in the developed geometry material are valid and reliable. The 18 HOTS items that have been



developed represent two HOTS indicators, namely analyze and evaluate. 16 items represent analyze indicators (C4) and 2 items represent evaluate indicators (C5). This HOTS test instrument can be used to evaluate students' HOTS abilities further. Moreover, based on research findings, it is known that 52.7 percent of students have very poor HOTS abilities; therefore, additional studies to improve students' HOTS abilities are expected.

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