Development of a mathematics instructional media by utilizing geogebra to enhance junior high school students' Higher order thinking skills

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ABSTRACT

This study aimed to develop an interactive visual media called Geoactive (Geogebra interactive) by employing Geogebra to improve students higher order thinking skill (hots) in the learning of solid geometry. The media was developed by using the model of 4D from Thiagarajan, which consists of define, design, develop, & disseminate. The product testing was conducted in SMPN 2 BUA, and two validators validated the product. Results show that: (1) the Geoactive developed was declared valid with the average assessment score of 4.45 which was in the category of very good; (2) the interactive media developed was declared practical with its indicator of the average of learning implementation being 78.67% which was in the category of good and the score of students' response was 2.89 which was categorized as good; (3) the Geoactive developed was effective with the completeness indicator of conceptual understanding and problem solving was 77,14% and 71,43%, respectively. Both of the two scores were categorized as high.

Keywords: Media, Geoactive (Geogebra interactive), higher order thinking skills (HOTs), solid geometry

INTRODUCTION

Mathematics is a discipline that has abstract study objects so that it requires the art of thinking to study it. Mathematics is not limited to rules of arithmetic and operation, but more in-depth, mathematics contains a system of rules of thinking that are subject to the laws of logic / based on rationality. Mathematics is a science with the following characteristics: (1) has abstract objects, (2) relies on an agreement, (3) has a deductive mindset, (4) has empty meaning symbols, (5) pays attention to the universe of speech, and (6) consistent in the system. Due to the complex nature of mathematics, it is crucial for the activists to develop logical, systematic and analytical thinking skills.

Geometry as a branch of mathematics, also inherits the above characteristics. So to master it, the ability to interpret geometrical ideas becomes simpler is needed. The ability to interpret ideas in geometry is complicated and not many students can master it (Nur'aini, 2017). This is due to the failure of students in understanding the concept of geometric structurally. The pattern of ideas in their minds is random, in no order, so it's so complicated to make the right decision. Therefore, learning geometry must begin with a simple way, from concrete to abstract, from the intuitive to the analysis, from exploration to mastery in a long period, and from the simplest to the highest stages. In this way, students can build their ability to solve geometry problems.

Fitriyani & Sugiman (2014) explain that problem solving is one of the abilities students must master in learning mathematics. Therefore, the teacher, as a learning facilitator, should develop and train students' problem-solving abilities programmatically according to the learning process standards. In essence, problem-solving is shown as an orientation and learned skills, which show that students can synthesize information and by trial and error, try to find solutions to these problems.

Learning geometry has a greater opportunity to be understood by students compared to other branches of mathematics. This is because students have known geometrical ideas before they entered school, such as lines, plane and space (Budiarto in Ma'rufi, Pasandaran & Yogi, 2018). However, the facts are the opposite. In the learning of polyhedra in SMP Negeri 2 Bua, students could distinguish prisms but could not explain the meaning of surface area. Students could mention the notion of angles, edges, areas of a prism, but could not show the surface area of a prism. Something is interesting about this case. The researcher interprets this as a failure of students in orienting their concepts and skills in understanding the term "surface area of prism". Student learning outcomes on this material were also relatively low. Based on the analysis, the results of the Odd Semester Final Examination results for the 2018/2019 academic year showed that the absorption ability of eighth-grade students of SMP Negeri 2 Bua totaling eight classes, on the competency standard, the surface area of polyhedra is still below average (45.5%). The low learning outcomes has been sufficient enough to explain that the students' visual ability of geometrical objects was also low. The visual ability must be possessed by students when learning geometry because, in the content, there are objects that can be drawn. The fact that the opposite occurs since student learning activities in understanding the surface area of the prism see the model of the solid geometry only without exploring it further. Student activities were not following the principles of constructivism learning. They did not actively build their knowledge through observing, reasoning, asking questions, exchanging ideas, and concluding. These five learning activities are the basic ideas of as Higher Order Thinking Skills (HOTS).

According to Thomas & Thorne, Higher order thinking is thinking at a higher level than memorizing facts or telling something to someone exactly as told to you (Apino & Retnawati, 2017). Learning with a high-level thinking orientation can be realized with the use of visual media. The aim is to make it easier for students to analyze the concept of solid geometry by looking at the model of a concept through animations and special displays. The use of technology has greatly supported the development of this visual media. One of the software that can be used is GeoGebra (Hohenwarter et al., 2008). The use of GeoGebra allows students to build their visual experiences through interactions with geometrical concepts. This application has an attractive appearance and is relatively easy to use. The ease lies in manipulating various geometric objects so that they are expected to increase student interest & creativity in learning while increasing students' understanding of the concepts they have learned and as a means to introduce or construct new objects (Asngari, 2015).

Therefore, researchers consider that the development of visual media like this is a breakthrough in terms of innovation in mathematics learning. It is called innovation because, in one media, it has two dimensions of objectives which are aimed at making it easier for students to interpret concepts and build student learning interactions in class. Based on this rationale, researchers gave the name of the developed visual media as Geoactive, which is an acronym from Geogebra Interactive.

To sum up, the problem formulated in this study is how valid, practical, and effective the use of Geoactive media is in learning of polyhedra of students of SMP Negeri 2 Bua. The purpose of this development research is to describe the level of validity, practicality, and effectiveness of the results of the development of Geoactive media, in polyhedral learning of the students in SMP Negeri 2 Bua.

RESEARCH METHODS

This type of research is research and development. The media developed is visual media aided by Geogebra through interactive learning with the term Geoactive (Geogebra Interactive) which meets valid, practical, effective criteria. This research was conducted at SMP Negeri 2 Bua in the academic year of 2018/2019.

The research design used in this study was Thiagarajan's 4-D development model. This model is a learning development approach system which is implemented through 4 (four) stages, namely Define, Design, Develop, and Disseminate.

Data were collected through observation, questionnaires, and tests. The observation process was carried out to obtain data on student learning activities, while the questionnaire (response) aimed to explore student responses about the use of media that had been developed. Data from these two techniques were then used to measure the practicality of the textbooks developed. Measurement of the effectiveness of textbooks is done by looking at the achievement of student learning outcomes. Learning outcomes were measured through tests of conceptual understanding and problem-solving that represent aspects of higher-order thinking.

Data analysis was carried out qualitatively and quantitatively. Quantitative data were obtained from student learning activity questionnaire sheets, student response questionnaires, and concept understanding & problem-solving tests. Qualitative data were in the form of suggestions, comments and criticisms from the validators. The data were then analyzed to measure the degree of validity, practicality, and effectiveness of the developed media. The complete data analysis technique is described as follows.

1. Validity Analysis

According to experts Lawshe and Martuza (in Ruslan, 2009) discuss statistical methods to determine the content validity and overall reliability of a test through expert judgment. The overall relevance of the two experts is Gregory's content validity, which is a content validity coefficient. The content validity coefficient can be calculated using the following formula:

$$\text{Content Validity} = \frac{D}{A + B + C + D}$$

A = The cell that shows the two assessors/experts declares irrelevance
B and C = The cell that shows differences in views between assessors/experts
D = The cell that shows both assessors/experts for content validity

Following is a model of the agreement for content validity:

		Validator I	
		Irrelevant Score (1 – 2)	**Relevant Score (3 – 4)**
Validator II	**Irrelevant Score (1 – 2)**	**A**	**B**
	Relevant Score (3 – 4)	**C**	**D**

Figure 1. The Model of Agreement between two experts (Ruslan, 2009)

To decide whether alternative assessment tools have sufficient degrees of validity, the agreement model is used with the assessment criteria of the two validators having a "strong relevance". If the result of the content validity coefficient is high (V> 75%), it can be stated that the results of the measurements made are valid. However, if this is not the case, then it is necessary to make a revision based on the suggestions given by the validator team or by looking at aspects that are of less value. Then the re-validation process for the revised device is performed. The process will continue until valid results are obtained.

2. Practical Analysis

Practicality analysis was done by processing data obtained from observation sheets of student activities and student questionnaire responses. Data from the observation sheet and questionnaire responses of students to learning using Geoactive interactive visual media developed were analyzed with the following steps.

a. Observation Sheet

The results of the observation sheet were calculated from the number of observers who chose "Yes" for positive statements and the number of observers who chose the answer "No" for negative statements. Then the results obtained are calculated with the following calculation guidelines:

$$\text{Observation Percentage } (p) = \frac{y + t}{n} \times 100\%$$

y = The number of “yes” answer (has positive value)
t = The number of “no” answer (has a negative value)
n = The number of the whole answers

Furthermore, the percentage that has been obtained was converted into qualitative criteria using the practical criteria table guidelines as follows.

Table 1. Criteria for practicality on observation sheets

Percentage Range	Criteria
$p \geq 85$	Very Good
$70 \leq p < 85$	Good
$50 \leq p < 70$	Fair
$p < 50$	Not Good

The practicality of the use of Geoactive interactive visual media in learning is said to be practical if the assessment of observations minimally reaches *good* criteria.

b. Student Questionnaire

Analysis of student response questionnaire data can be done with the following steps:

1) Tabulate data obtained from students. The student response questionnaire was prepared with four answer choices namely SS (Strongly Agree), S (Agree), KS (Less Agree), TS (Disagree) with the assessment guidelines as presented in Table 7.

Table 2. Guidelines for scoring student questionnaire responses

Category	Score	
	Positive Statement	Negative Statement
Strongly Agree (SS)	4	1
Agree (S)	3	2
Less Agree (KS)	2	3
Disagree(TS)	1	4

2) Compile a classification table with the highest score of 4 and the lowest score of 1 (based on the scale of grades 1-4), the number of class intervals of 4 (based on classification division), and the calculation of the interval is 0.75

$$\text{Interval} = \frac{4-1}{4} = 0{,}75$$

Based on these data, a student classification table for learning using Geoactive interactive visual media was developed based on the total mean obtained.

Table 3. Practical criteria for student response questionnaire

Total	Criteria
$3{,}25 < \bar{x} \leq 4{,}0$	Very good
$2{,}5 < \bar{x} \leq 3{,}25$	Good
$1{,}75 < \bar{x} \leq 2{,}5$	Fair
$1{,}0 < \bar{x} \leq 1{,}75$	Poor

$\bar{x}$ = Total mean

The practicality of Geoactive interactive visual media is determined by calculating the total mean, then matching it to Table 3. Geoactive interactive visual media developed is said to be practical if the minimum criteria achieved were *good*.

3. Effectiveness Analysis

The effectiveness analysis was performed using the HOTS test based on conceptual understanding and problem-solving. The test results were assessed based on the scoring guidelines that have been made. Geoactive interactive visual media is said to be effective if the percentage of completeness reaches a minimum of 70% ($t \geq 70\%$). The analysis is carried out with the following stages:

a. Calculating student test score (N)

b. Determine the categories of students' conceptual understanding and problem-solving abilities. Guidelines in determining the categories of students' conceptual understanding and problem-solving abilities, according to Arikunto (2006) can be seen in Table 4.

Table 4. HOTS Ability Categories

Range (*N*)	Category
$80 < N \leq 100$	Very high
$60 < N \leq 80$	High
$40 < N \leq 60$	Fair
$20 < N \leq 40$	Low
$0 < N \leq 20$	Very low

c. Calculate the percentage of students who have an understanding of concepts and problem-solving in the high category. The calculation was done using the following formula:

$$t = \frac{x}{n} \times 100\%$$

t = the percentage of students having a minimum understanding of concepts and problem-solving in the high category.
x = the number of students who have a minimum understanding of concepts and problem-solving in the high category.
n = the number of students who took the test.

RESULTS AND DISCUSSION

Research Results

The trial run produced practicality and effectiveness data on media usage. Practicality data was obtained from student activity observation sheets filled out by observers.

1. Results of Validity and Product Trial

a. Validity Quality

The results of the validation of the media by the validators are presented in the following table.

Table 5. Results of the media assessment questionnaire by the validator

Assessment Aspect	**Score**		**Mean of each aspect**
	Validator 1	**Validator 2**	
Suitability of material/content	47	39	4.3
Conformity with the concept understanding approach	15	12	4.5
Compliance with the problem-solving approach	15	14	4.8
Language	19	17	4.5
Total score	178		
Mean score	4.45		
Criteria	Very good		

Table 5 shows that mean of each aspect of the assessment is in the range 4.2 - 5.0 or ($4.2 < \bar{x} \leq 5.0$). So, it can be said that both validators assess the products developed under the category of "very good "and the media developed are in accordance with the curriculum, the characteristics of understanding concepts and problem-solving, and the language used is in accordance with the rules of writing and communicative. In addition, the table above shows that the mean of the two validators was 4.45 with the criteria of "very good". This shows that the developed media is valid and worth testing.

b. Practicality Quality

The assessment of practicality quality can be seen from two sources, namely the observation sheet of student activity during four lessons and the student response questionnaire given at the fifth lesson. Tabulation of student activity observation sheet data and student response questionnaires can be seen in the Appendix. The results of the data analysis can be seen in the following explanation.

1) Observation sheet for student activities

Learning took place for four lessons. At each lesson, student activities related to the use of visual media were observed. There are two observers in each study where each observer observed three groups. The results of a complete observation sheet data analysis can be seen in Table 6.

Table 6. Results of observation of student activities

Lesson	**Percentage (%)**	**Criteria**
First lesson	61.76	Fair
Second lesson	82.35	Good
Third lesson	85.29	Very good
Fourth lesson	85.29	Very Good
Mean Percentage	78.67	Good

Based on the results of the above table, it can be seen that learning had proceeded as expected. That way, the media developed were practically used in learning, with an average percentage of 78.67% with good criteria.

2) Student response questionnaire

The student response questionnaire was filled by all students of class VIIIB, totaling 35 students. Classically, the mean of the total questionnaire responses of students reached 2.89 with good criteria. Based on the practicality criteria of student response questionnaire, it shows that the developed media is practically used in learning. The students' responses to the use of media are presented in the following table.

Table 7. Results of student response questionnaires

Assessment Aspects	Score	Mean	Criteria
Attention	678	2.77	Good
Excitement	189	2.70	Good
Confidence	604	2.88	Good
Satisfaction	549	3.14	Good
Total	2020	2.87	Good

Based on Table 7, it can be seen that the four aspects of student responses observed were in good criteria with an average total questionnaire of student responses reaching 2.87 with good criteria.

From the student response questionnaire sheet, comments were also obtained from students regarding the use of media in learning. Some positive comments given by students include the media used so well that it makes it easier for students to understand the material, the presentation of the media is interesting - the shapes, colors, fonts and images used to the activities. As for negative comments, one of them is that the media used are difficult and make students confused.

c. Quality of Effectiveness

The assessment of the quality of effectiveness is seen from the results of the HOTS test-oriented to the understanding of concepts and problem-solving in class VIIIB students' literacy. The test was carried out at the last lesson. The test consists of four questions, where the conceptual understanding and problem-solving each consists of two questions.

Based on the results of the written test analysis, the highest score obtained by students from the concept understanding questions was 88.89 with the total score obtained was 8 while the lowest score was 22.22 with the total score obtained by students was 2. The highest score obtained by students from the questions of problem-solving was 92.86, with the total score obtained by students was 26. While the lowest score was 35.71, with the total score obtained by students was 10. The results of the complete test analysis can be seen in the following table.

Table 8. HOTS Test Results

Student's Mastery Learning	Number of students	
	Concept understanding	Problem Solving
Students who satisfy the minimum criteria of mastery learning (minimum category is high)	27	25
Students who do not satisfy the minimum criteria of mastery learning (maximum category is high)	8	10
Percentage of Mastery Learning (%)	77.14	71.43

HOTS test analysis results concerning the understanding of concepts and problem-solving students show that the percentage of mastery learning for understanding concepts is 77.14%, and the percentage of mastery learning for problem-solving is 71.43%. The percentage obtained shows that the developed media is effectively used in learning.

d. Dissemination

The dissemination stage is the stage of using tools that have been developed through the stages of expert validation and revision. In this research, the stage of media dissemination is carried out through a process of socialization to teachers or schools. The dissemination was only limited to the provision of soft media copy to mathematics teachers of state junior high school.

Discussion

a. Validity

It has been stated in the validity analysis that the developed visual media has fulfilled the validity criteria. The validity of visual media was assessed by two validators. As stated by Sugiyono (2012) that validation is done by presenting experienced experts to assess new products that have been designed so that the weaknesses and strengths of the product can be known.

Based on the results of the analysis of these data, by averaging the results of the assessment of the two validators, it shows that the developed visual media has met the valid criteria. This is evidenced by the fulfillment of $\bar{x}$ for all aspects of each development that are in very good classification. The testing of instruments tested was carried out with "rational analysis or professional judgment".

b. Practicality

It has been stated in the practicality analysis that the developed visual media has fulfilled the practical criteria both in terms of feasibility and implementation. The practicality of a developed learning tool can be seen from the level of ease and assistance in its use. The tool meets the practicality criteria if the response given to the device is good.

The feasibility of visual media can be seen from the results of the analysis of student questionnaire responses. Out of 35 students, three students responded very well, and 26 students who responded good to the use of visual media during learning. In the analysis conducted, it was found that on average, all aspects of the assessment, which included aspects of attention, excitement, confidence, and satisfaction were in good criteria. Besides, the use of visual media can be seen from the results of the analysis of student activity observation sheets. The results of the analysis of learning management for four lessons are in the criteria of "Good" ($70 \leq p < 85$) so that the use of the developed visual media is good to be used in learning.

c. Effectiveness

Based on the results of the effectiveness test, the developed visual media has fulfilled the effectiveness criteria. Effectiveness is tested by giving tests based on conceptual understanding and problem-solving. Measuring the effectiveness of a product developed can be done in several ways - measuring student test scores, observing the learning process, and evaluating students' learning.

The results of the analysis of the conceptual understanding and problem-solving tests show that the percentage of students mastery learning was above 70%. Some of the findings and obstacles obtained and faced by researchers during the development process of Geoactive interactive visual media are described as follows:

a. *Define*

This research develops HOTS-based visual media with an orientation to the ability to understand concepts and problem-solving. Achieving the understanding of concepts and solving students' problems in mathematics is not an easy thing because the understanding of a mathematical concept is carried out individually. As we know that each student has different abilities in understanding concepts and solving mathematical problems. While the facts in class indicate that the level of student knowledge is only at the level of memorizing formulas. Suherman (2001) suggests that the core of mathematics is understanding. No matter how great the students are in memorizing the various formulas, it will not be useful if they do not understand the basic concepts. Understanding the concept is the main capital in mastering mathematical material. The obstacle faced by researchers is how to develop visual media that contains both abilities in order to improve student learning outcomes or achievements. Understanding also relates to the way students form the process of proof or discovery of a formula. In general, it has been agreed that students' understanding of mathematical reasoning "tends to develop from inductive to deductive and towards greater generality". The hierarchy of mathematical reasoning emphasizes the development of the inductive to deductive mindset, but they fail to explain adequately about the way they think. In this case, students make the transition of thought from inductive reasoning to deductive but weak in terms of presenting the basic ideas they make. (Eric Knutha, Orit Zaslavskyb, Amy Ellisc, 2019).

b. *Design*

The obstacle at this stage is the development of learning tools that only accommodate one ability. The next obstacle related to fonts and images that will be used in visual media. The selection of fonts and images were repeatedly conducted by researchers with the aim that students are interested in visual media the first time they are given visual media.

c. *Develop*

Regarding the implementation and management of learning, at the beginning of the lesson, learning was still not conducive or not good as students were not familiar with learning that utilizes visual media. When given visual media, students were still very enthusiastic, but when they were directed to work on the questions, they do not understand the use of visual media.

Regarding the use of visual media during the learning process, it appears that students were motivated to learn visual media. If there was unclear material, they tried to understand it by asking students of other groups or asking the teacher directly. In addition, students actively worked on all the problems contained in the visual media. Sudjana (2004) states that student activeness can be seen in terms of: (1) Participating in carrying out learning tasks; (2) Involved in problem-solving; (3) Asking other students or teachers if they do not understand the problems they face; (4) Trying to find various information needed for problem-solving; (5) Carry out group discussions in accordance with the instructions of the teacher; (6) Assessing his abilities and the results obtained; (7) Train themselves in solving similar problems; (8) Opportunities to use or apply what is obtained in completing the task at hand. The obstacle faced in every lesson is that there are always students who carry out other activities outside the learning process such as working on other subject assignments and male students who played a lot and disturbed other students.

When given a conceptual understanding and problem-solving test, it is concluded that the number of students who have completed the concept understanding problem is greater than the students who have completed the problem-solving problem. After the researchers conducted the examination, it was obtained the fact that most students were constrained in the step of re-checking the answers. Questions that were considered difficult by students are questions number 3 and 4. They were confused by the picture presented so that they identified what is known incorrectly. The difficulty at this stage is in accordance with the results of Septiyan's (2015) study which states that problem-solving skills are very important, and in addition to understanding the problem it is also important to determine the resolution of the problem. The main obstacle for students in solving problems is their weak rechecking skill since they relied on the way taught by the teacher without developing ways to solve a problem in their own way. (Zaslavsky, 2019) explained a number of ways to overcome the students' difficulties by getting students to think critically through a variety of varied examples.

CONCLUSIONS AND SUGGESTIONS

Conslusion

Based on the results of research and discussion, it can be concluded that Geoactive interactive visual media on learning polyhedra is appropriate for use in learning in terms of validity, practicality, and effectiveness described as follows: (1) Geoactive interactive visual media developed was declared valid with an average score of two validators of 4.45 in the *very good* category. (2) Geoactive interactive visual media developed was declared practical, with an average indicator of learning achievement reached 78.67% and was in the *good* category, and the average student response of 2.89 was in the *good* category. (3) Geoactive interactive visual media developed was declared effective with an indicator of mastery learning of concept comprehension of 77.14% in the *high* category and problem solving by 71.43% in the *high* category.

Suggestion

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