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Developing High-Order Mathematical Thinking Competency on High School Students' Through GeoGebra-Assisted Blended Learning

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ABSTRACT

Blended Learning has received considerable attention in the field of mathematics education in recent years. This study combines online learning and face-to-face based learning. Blended Learning is based on some of the weaknesses found in online learning. In Blended Learning, Online learning is not just the learning that collects teaching materials, assignments, exercises, tests, and results of students' works. It also has to be an interesting and attractive learning so that students' will have better understanding on learning objectives. One of the tools for developing interesting and attractive online learning process is an open source software called GeoGebra. Blended Learning has very good quality when applied in developing students' High-Order Mathematical Thinking Competency (HOMTC) as it is evident from previous researches. This study was an experiment based on pretest-posttest control group aiming to examine the influence of Blended Learning and students' initial mathematical ability on students' achievement and enhancement of HOMTC consisting of some aspects such as mathematical problem solving, mathematical communication, mathematical reasoning, and mathematical connections. The research subjects are 96 students' of grade XI IPA 1 SMAN I Gading Rejo in Lampung Province. The results showed that students' who learned Probability and Statistics under GeoGebra-Assisted Blended Learning (GABL) have higher HOMTC than students' who received Conventional Learning (CL). There is no differences on students' HOMTC enhancement between those receiving GABL learning and CL in terms of Initial Mathematical Ability (IMA). HOMTC aspects of the students' who learned by using BLGA that have the highest enhancement are mathematical connections followed by aspects of mathematical communication, mathematical reasoning and mathematical problem solving..

Keywords: Blended Learning, Online Learning, Geogebra, High-Order Mathematical Thinking Competency.

1. Introduction

In general learning model consists of offline learning and online learning model. Offline learning model is a direct face-to-face learning process between students and teachers at a time and place determined periodically. In offline learning, students only get the material, references, assignments, and explanations at the time of face-to-face with the teacher in the classroom and the student will acquire the knowledge, hone skills, and increase understanding of the material that is being studied through a reference that has been given the teacher in the classroom. Online learning model is a learning process between teachers and students that do not meet face to face directly in providing the theory and concepts of material, but the learning process will be conducted in online-based environments such as the Internet. In online learning, students are required to actively seek, explore, and learn the references given by the teacher (Kaleta, et al, 2003).

Online learning holds some weaknesses such as the absence of face-to-face interaction between students and teachers in the classroom because the learning process is done entirely in online based environment. Hence, the teacher cannot monitor the activity of students resulting on the lack of social interaction that is required in the learning process. However, the weakness can be overcome by combining offline and online learning model. Such learning model is known as Blended Learning.

Online learning should have nice and attractive appearance so that students will have better understanding on the learning objectives that are delivered. Software used in developing online learning interesting and attractive is an open source software called GeoGebra.

GeoGebra Assisted Blended Learning lets students to engage actively in the learning process and gives positive impact on students' ability to understand a concept. The use of information technology in GeoGebra Assisted Blended Learning also allows mathematics learning takes place effectively since students can explore the material presented, practice to use logical analytical, systematic, and critical mind, and creative thinking, have ability to cooperate in dealing with various problems and be able to utilize the information they receive. Moreover, the information technology can also quickly and accurately view the visualization of teaching materials.

Given the large contribution of information technology in GeoGebra Assisted Blended Learning to develop logical analytical, systematic, critical and creative thinking abilities which are indicator of the High-Order Mathematical Thinking Competency (HOMTC), the researchers made computer as a major tool in developing these abilities in this study. According to the NCTM (2000), in studying mathematics students are required to have the capability of reasoning, connection, communication, and mathematical problem solving. Those skills are HOMTC aspects.

2. High-Order Mathematical Thinking Competency

In general, high-order aspects of thinking according to Moursund (2003) is the ability to apply the facts to the new situation. The same opinion also delivered by Vui (2005) stating that high-order thinking skills will happen if someone links new information with information already stored in his memory and connects it together then develops the information to achieve a goal.

High order thinking by Whittington (1995) is the last of the three components of the revised bloom taxonomy: analysis, evaluation, and creation. Analysis is the ability to separate the material into parts or components that are smaller (simpler) so that the structure is more easily understood. Evaluation is assessing the ability of a material to an objective based on certain criteria. Assessment can be given in internal assessment (operational capabilities) and external assessment. External assessment includes correspondence between processes and goals as well as the fit between the procedures with the problem. Furthermore creation includes students to construct knowledge, make generalizations or establish procedures to resolve problems

According to Henningsen & Stein (Sumarno,2003) high-order mathematical thinking is the ability to have non-procedural thinking, among others including the following: the ability to search for and discover patterns and to understand the mathematical structure of the underlying relationships, the ability to use effectively and appropriately the facts available to formalize and solve problems, the ability to make significant mathematical ideas, the ability to think and reason flexibly through the preparation of conjecture, generalization and justification, as well as the ability to interpret the results of problem solving.

Webb & Coxford (Ratnaningsih, 2003) stated that the ability to understand implicit ideas, formulate a conjecture, analogy and generalization, have logical reasoning, solve problems, communicate mathematically, connect mathematical ideas with other intellectual activities are pertained to aspects of the high -order mathematical thinking. Based on this opinion it can be inferred that aspects of higher-order thinking abilities correspond to the characteristics of thinking involved. Mathematical communication capability includes ability to understand the idea implied and communicate mathematically. Mathematical reasoning capability includes ability to formulate a conjecture, analogy and generalization. Linking mathematical idea is categorized to mathematical connection capability and problem-solving ability is referred to mathematical problem solving. Thus a high order mathematical thinking skills include the ability to mathematical reasoning, mathematical communication, mathematical connections, and mathematical problem solving.

3. Blended Learning

The basic concept of this method is a combination of classroom study and personal use of interactive multimedia resources. According to Mayadas and Picciano (2007) the main purpose of learning blended learning for education institutions is to create positive attitude towards the learning process. Mayadas and Picciano (2007) define blended learning as a combination of face-to-face learning and online learning. In simple terms this method is a combination of traditional learning and online learning environments.

Blended learning comes in many forms and types. As described by Picciano (2006) blended learning can be used to improve the conventional learning with additional reading, electronics instructor, notes and graphic images which can hardly be done manually. In other process, blended learning is a combination of online learning with face-to-face lectures.

There are two core elements of blended learning (online and face to face), both of which are the basis for the definition of blended learning (Picciano, 2006). This means that the blended learning involves a mixture of different components that include programs, content, feedback, and many other things appropriately. According to Picciano (2006) blended learning in its broadest sense can be defined or conceptualized as a variety of technologies/media both online and offline that are integrated with the conventional classroom.

4. Geogebra-Assisted Blended Learning

GeoGebra is a dynamic mathematics software that combines geometry, algebra, and calculus. This software is developed for mathematics teaching and learning in schools by Markus Hohenwarter in 2001 at Florida Atlantic University. GeoGebra is a dynamic geometry system by which users can do constructions with points, vectors, segments, lines, conic sections, as well as functions and change them dynamically afterwards. On the other hand, equations and coordinates can be entered directly. Thus, GeoGebra has the ability to handle variables for numbers, vectors, and points, find derivatives and integrals of functions and offer commands like Root or Extreme Value.

The latest version of GeoGebra up until this research is done is V4.2.60 consisting of algebra display, chart display and spreadsheet view. Another advantage of this software is it is an open source so we do not have to pay a license to use it and the ultimate advantage of this software needed for online learning is its capability to export program results made in the Hyper Text Markup Language (HTML). The results of the exported program created in Geogebra to HTML can be modified by adding some syntax java-scripts to decorate the view. The use of Geogebra in online learning creates interesting and attractive appearance hence students will have better understanding on the learning objectives.

5. Research Methodology

This study is quasi-experimental research since it employs treatment manipulation and the sampling method was carried out on existing groups. This study uses three groups, two experimental groups and one control group. The first experimental group was treated with GeoGebra Assisted Blended Learning (GABL), the second experimental group was given GeoGebra Assisted Conventional Learning (GACL) and the control group was given Conventional Learning (CL). At first, the three groups were given prerequisite tests, the results of these tests are used to classify students into three competency namely the high, middle and low. The study design is described as follows:

O	X_1	O	
O	X_2	O	
O		O	(Ruseffendi, 1994)

The population of this study is students of State Senior High School (SSHS) 1 Gadingrejo Lampung Province. Considering adequate infrastructures and facilities in SSHS 1 Gadingrejo necessary needed to support the research, the researchers decided to conduct the study in this school. The number of sample in each class in this study are 32 students, so the total subject sample in this study are 96 students consisting of class XI.SCIENCE.3 as the first-class experiments using GeoGebra Assisted Blended Learning (GABL) (X1), class XI.SCIENCE.4 as the second class of experiments using GeoGebra Assisted Conventional Learning (GACL)(X2) and XI.SCIENCE.2 as the control class. Before given the learning treatment, all three groups were given an initial test (O) on HOMTC. After administering the treatment, all three groups were given a final test (O) on HOMTC

6. Result And Analysis

6.1. Empirical Results

6.1.1. Description of HOMTC Initial Test

Data of initial test was obtained from the test result of mathematical thinking ability that measured reasoning, communication, connection and mathematical problem solving ability before the learning treatment is given. Data of Students' HOMTC Initial Test is described in Table 1 as follows:

Table 1. Result of Students' HOMTC Initial Test based on IMA

Level of IMA	Type of Learning	Score		
		Mean	***s***	***n***
High	GABL	18,30	6,07	10
	GACL	18,40	6,64	9
	CL	17,33	5,11	8
Middle	GABL	17,43	8,05	14
	GACL	17,88	5,10	15
	CL	16,88	8,07	15
Low	GABL	16,00	5,58	8
	GACL	16,89	6,75	8
	CL	15,87	7,16	9
All	GABL	17,34	6,76	32
	GACL	17,84	5,81	32
	CL	16,53	6,10	32

Note: Maximum score is 120

From Table 1 we can see that the score of the class that will receive GABL in overall is relatively higher than two other classes. Based on the level of IMA there is relatively slight difference among the three categories. Students that will receive GACL in the high IMA category got the highest score compared to other groups. The results are contradictory with the scores of middle and low IMA level that students in the class that will receive GABL got higher mean score than two other classes. In order to understand the initial condition of the groups thoroughly it is imperative to further examine the data with statistical test i.e. compare mean test as described in the following Table 2

Table 2. Anova of Students' HOMTC Initial Test based on IMA

Level of IMA	Type of Learning	***F***	***P-Value***	Decision
High	GABL × GACL	0,234	0,635	Accept H_0
	GABL × CL	0,280	0,604	
	GACL × CL	0,000	0,996	
Middle	GABL × GACL	0,153	0,699	
	GABL × CL	0,272	0,606	
	GACL × CL	1,057	0,313	
Low	GABL × GACL	0,367	0,554	
	GABL × CL	0,180	0,677	
	GACL × CL	0,026	0,875	
All	GABL × GACL	0,082	0,775	
	GABL × CL	0,091	0,764	
	GACL × CL	0,360	0,551	

H_0: There is no difference on HOMTC Initial Test based on students' IMA

Table 2 shows the *p-value* of each IMA category are greater than $\alpha = 0,05$ so H_0 is accepted. Hence it can be concluded there is no significant difference on HOMTC Initial Test based for the three IMA categories (high, middle and low). The result confirms that in this study the research subject has the same initial HOMTC ability so the learning treatment that will be given will not be bias due to the difference on initial HOMTC ability.

6.1.2. Description of Final Score Test and HOMTC Normalized Gain

Table 3 below provides an overview of student HOMTC enhancement after the final test. The data consists of score mean and HOMTC *normalized gain* based on each IMA category.

Table 3. Description of Final Score Test and HOMTC Normalized Gain

IMA Level	Type of Learning	Max Score of Final Test	Mean		Mean	
			Final Test Score	SD	Normalized Gain	SD
High	GABL	110	90,700	10,209	0,716	0,093
	GACL	93	74,440	11,685	0,558	0,116
	CL	72	64,630	5,854	0,461	0,042
Middle	GABL	103	88,500	9,882	0,692	0,095
	GACL	81	72,800	5,759	0,535	0,061
	CL	76	62,200	7,408	0,447	0,046
Low	GABL	93	83,880	7,882	0,655	0,065
	GACL	78	69,880	7,060	0,513	0,051
	CL	74	64,670	8,185	0,464	0,048
All	GABL	110	88,030	9,597	0,690	0,088
	GACL	93	72,530	7,166	0,536	0,078
	CL	76	63,500	8,024	0,455	0,045

Maximum Score = 120 SD = Standard Deviation

According to Table 3 the mean score of HOMTC final test on GABL group is higher than the two others at all IMA level. This apparently shows that GABL will enhance students' HOMTC. Furthermore the highest mean of HOMTC *normalized gain is* obtained by students with high IMA level and the lowest is gained by students with middle IMA category in CL class. Thus it can be concluded that GABL is appropriate to all IMA categories but this tendency needs further study by using inferential statistics test in Table 4 below:

Table 4. Anova Result of HOMTC *Normalized Gain* Based on Learning and IMA

Source	DF	SS	RSS	F	*P-Value*	Decision
Learning (A)	2	0,825	0,412	77,311	0,000	Reject H_0
IMA (B)	2	0,015	0,008	1,445	0,241	Accept H_0
A X B	4	0,012	0,003	0,559	0,693	Accept H_0

According to Table 4, for learning factor H_0 is rejected, it means that at least two of HOMTC enhancement from students who receive GABL, GACL and CL have significant difference. As for IMA factor H_0 is accepted, meaning that there is no significance HOMTC enhancement on students with high, middle and low IMA. The result of interaction between learning and IMA factor on student HOMTC enhancement is accepting H_0, meaning there is no interaction between learning and IMA factor on student HOMTC enhancement. Table 4 also concludes that learning has significant effect on student HOMTC enhancement but the difference on student IMA level does not the same effect therefore the student HOMTC enhancement is not depended on student IMA.

6.1.3. Enhancement on HOMTC Aspects based on Type of Learning and IMA

As mentioned earlier HOMTC aspects consist of mathematical reasoning ability, mathematical communication, mathematical connection and mathematical problem solving. In order to find out which learning has better result on each HOMTC enhancement further analysis is required. Table 5 presents description of HOMTC aspects score based on learning and IMA.

Table 5. Result of HOMTC Normalized Gain Based on Learning and HOMTC Aspects

Source	DF	SS	RSS	F	*P-Value*	H_0
Learning (A)	2	3,674	1,837	101,485	0,000	Reject
HOMTC Aspects (B)	3	0,803	0,268	14,784	0,000	Reject
A × B	6	0,490	0,082	4,515	0,000	Reject

Then we use Tukey test to see mean difference on of HOMTC aspects enhancement. The result is shown in the following Table 6.

Tabel 6. Tukey Test on HOMTC Normalized Gain based on HOMTC aspects

HOMTC Aspects (I)	HOMTC Aspects (J)	Mean Difference (I – J)	P – Value	H_0
Reasoning	Communication	0,0767	0,001	Reject
	Connection	0,0210	0,700	Accept
	Problem Solving	0,1160	0,000	Reject
Communication	Connection	-0,0556	0,023	Reject
	Problem Solving	0,0394	0,180	Accept
Connection	Problem Solving	0,0950	0,000	Reject

According to Table 5 we rejected H_0 of learning factor meaning that at least two of student HOMTC enhancements who receive GABL, GACL and CL have significant difference. The same results also occur on HOMTC aspect, it means that there is difference on HOMTC aspects enhancement reasoning, communication, connection and problem solving.

Table 6 shows there are no significant mean difference on mathematical reasoning ability and mathematical communication and between mathematical communication and mathematical problem solving. Meanwhile other HOMTC aspects have significant mean difference and mathematical reasoning is the HOMTC aspect that has significantly better enhancement compare to mathematical communication, mathematical connection and mathematical problem solving

In the interaction between learning factor and HOMTC aspects on student HOMTC enhancement H_0 is rejected meaning that there is significant interaction between learning factor and student HOMTC aspects that affect HOMTC gain. So it can be concluded that learning factor and HOMTC aspects all together affect HOMTC gain.

6.2. Analysis

6.2.1. Learning

This study suggests that students who study mathematics with GABL experience HOMTC enhancement by 69% while students who study mathematics with GACL have HOMTC enhancement by 54% and students who study mathematics with CL have HOMTC enhancement by 46%. It shows that students who receive GABL have much higher enhancement as compared to those who receive GACL and CL. Students who learn with GACL also have higher enhancement than those who learn with CL.

The HOMTC enhancement through the use of information technology is due to the fundamental difference that occurs during the learning process, the group of students who learn without the use of information technology gain knowledge of facts, concepts and procedures only from teachers and textbooks.

Conversely, in learning by using information technology students not only learn from teachers and textbooks, but also get assistance from information technology, especially the internet. Students can learn from a variety of sources available on the internet. Information technology also helps students to have better understanding on the knowledge of facts, concepts and procedures presented in teaching materials and since teaching materials are created in computer-based they become more informative and communicative.

The computer-based teaching materials have more accurate visualization. The visualization presented is interesting because it can be moved, the shape and size can also be changed providing an opportunity for students to explore and observe easily. Exploration is very necessary when students are trying to understand a concept to construct knowledge.

6.2.2. Initial Mathematical Ability (IMA)

By applying GABL it is evident that student HOMTC enhances by 72% for students with high IMA category. The result is better compare to HOMTC enhancement of students with middle and lower IMA categories which are respectively 69% and 65%. It can be concluded that for all IMA categories GABL contributes by more than 65% to student HOMTC enhancement. Applying GACL enhances student HOMTC by 56% for students with high IMA

category which is better if compared to students with middle and low IMA categories which are respectively 54% and 51% so it can be inferred that GACL improves student HOMTC by more than 50% for all IMA categories. Students with high IMA category who receive CL achieve 46% HOMTC enhancement which is better compare to those with middle and low IMA categories which are respectively 45% and 46% or in other words CL enhances student HOMTC by 45% in all IMA categories.

Although statistically IMA has no significant difference on student HOMTC enhancement but descriptively it is evident that HOMTC enhancement for students with high IMA category is greater than students with middle and low IMA categories. Observing the interaction between learning and IMA factors on student HOMTC enhancement leads to a conclusion that student HOMTC enhancement does not depend on IMA. However, when careful observation is done on learning with computer facilities it is evident that students with high IMA category achieve higher HOMTC enhancement.

6.2.3. High-Order Mathematical Thinking Competency (HOMTC)

Students HOMTC in this study includes mathematical reasoning, mathematical communication, mathematical connection and mathematical problem solving. Among those aspects, mathematical connection has higher enhancement compare to three other aspects by applying GABL. The enhancement of mathematical connection is demonstrated by student's ability to understand the link between mathematical skills and other subjects

Mathematical communication skill is another HOMTC aspect that has the second highest enhancement. It is showed by student ability to understand representation in the form of graphs, tables and notation. GABL characteristics that uses computer and GeoGebra in the form of visualization trains students to understand picture and visualization materials.

Next aspect of HOMTC that enhances is mathematical reasoning ability. Students' skills in reasoning is visible when they undertake exploration activities and observations easily to learn a concept with the material presented with computer technology. Students think creatively when they tried every possibility and think critically when they shape knowledge. GeoGebra used during learning process triggers student reasoning ability. Furthermore since BLBG applies online and offline learning it provides an opportunity for students to ask questions, exchange opinions and discussions in online discussion forums and face-to-face classroom sessions help student improving their mathematical reasoning.

HOMTC Aspects on problem-solving ability is noticed when students are competent to represent the problem and understand the mathematical concepts contained in the problem. This is because in GABL students are exposed to a variety of problems and they have to focus on the process of solving the problems resulting on enhancement of student's ability to overcome the reality of the problem. Furthermore student ability to understand the link between real problems with mathematics triggers students' intrinsic motivation, because it convinces them that math is not distant from everyday life, but mathematics is part of daily life activity.

7. Conclusions

Based on the results and analysis, it can be concluded : (1) There are differences in students' HOMTC enhancement for the three learning method applied; (2) at all IMA levels, HOMTC of students who receive GeoGebra assisted Blended Learning is higher than students obtaining the two other learning; (3) There is no difference in HOMTC enhancement for the three applied learning in terms of students' IMA; (4) There is no interaction between learning and students' IMA with student HOMTC; (5) high IMA category resulted in the highest HOMTC enhancement compared to two other learning; (6) There are differences in HOMTC aspects enhancement (mathematical reasoning, mathematical connections, mathematical communication and mathematical problem solving) for the three learning applied; (7) There is no difference in HOMTC aspects enhancement for the three applied learning in terms of students' IMA; (8) The highest HOMTC aspect enhancement of students who receive GABL is the ability to mathematical connection, followed by mathematical communication skills, mathematical reasoning and mathematical problem solving.

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