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Implementation of Web-Assisted Brain-Based Learning to Enhance Students' High-Level Mathematical Thinking Skills

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Abstract

High-level mathematical thinking skills are important for the development of student knowledge. However, students' abilities in this matter are still very weak, so they need to be developed. Web-assisted brain-based learning is alternative learning that is expected to enhancing students' high-level mathematical thinking skills. The main objective of this study is to analyze the achievement and enhancement of students' high-level mathematical thinking skills comprehensively as a result of the implementation of web-assisted brain-based learning and conventional learning. This study used a quantitative method with a pretest-posttest control group design. The study population included all students in the mathematics department from one of the universities in Central Java. The sample was a group of students who take Integral Calculus subjects and they were students of Mathematics study programs and Mathematics Education study programs. For each study program, the sample choosed two classes randomly, the experimental class was taught by using web-assisted brain-based learning, while the other class was taught by using conventional learning as a control class. This research used various instruments. They were Mathematical Prior Knowledge Test, High-Level Mathematical Thinking Skills Test, and Observation sheet. Data were analyzed using t-test, t'-test, Mann-Whitney U test, and two ways ANOVA. This study concluded that: (1) the achievement and enhancement of high-level mathematical thinking skills of students taught by using web-based brain-based learning is better than the achievement and enhancement of those taught by using conventional learning; (2) there is no interaction between learning (web-assisted brain-based learning and conventional learning) and mathematical prior knowledge (high, medium, low) on the achievement and enhancement of students' high-level mathematical thinking skills; (3) there is an interaction between learning (web-assisted brain-based learning and conventional learning) and the type of study program (mathematics and mathematics education) towards the achievement and enhancement of students' high-level mathematical thinking skills.

Keywords: *Web-Assisted Brain-Based Learning, High-Level Mathematical Thinking Skills*

1. Introduction

High-Level Mathematical Thinking skills are important for the development of student's knowledge, in order to be able to solve mathematical problems given by using good reasoning, illustrate mathematical ideas into mathematical models then connect them to other mathematical concepts in real life and other scientific disciplines. Therefore, it can be said that High-Level Mathematical Thinking skills is very important and must be mastered by students. According to Webb & Coxford (1993), High-Level Mathematical Thinking skills include the skill to understand mathematical ideas more deeply, observe data and explore implied ideas, construct conjectures, analogies and generalizations, reason logically; solve problems, communicate metematically, and associate mathematical ideas with other intellectual activities.

Various studies that have been carried out have resulted in findings that High-Level Mathematical Thinking skills are still relatively weak (Henningsen & Stein, 1997; Herrington & Oliver, 1999; Herman, 2007; Miri, et al., 2007; Nurlaelah, 2009; Setiawan, et al. , 2012; and Susanti, 2012). The results of preliminary research conducted by Dewi (2017) on 38 students

who took the Integral Calculus course at one of the tertiary institutions in Central Java also showed that the mean score of students' High Mathematical Thinking Ability was 21.28 with a standard deviation of 5.91 from an ideal score 58. The achievement of students' mathematical thinking ability is included in the low category. Weak skills of High-Level Mathematical Thinking is allegedly because learning mathematics in higher education does not take place optimally.

Integral Calculus Courses are subjects that obtained by students in the first year of lecture and become prerequisites for various courses in other semesters. In studying Calculus, students need to have a High-Level Mathematical Thinking Skills. This is because the characteristics of Calculus itself are (1) abstract, (2) requires reasoning ability, (3) requires analytical understanding, (4) involves a lot of graphics and images and (5) is widely applied in real life and other scientific disciplines.

Efforts to enhance the High-Level Mathematical Thinking Skills need to pay attention to the mathematical prior knowledge of students. This is because mathematical material that is systematic in nature, concepts that are owned by students are prerequisites of the concepts to be learned. Students will associate the new knowledge they have with the mathematical prior knowledge they have (Hidayat, 2004; Ruseffendi, 2006; Wahyudin 2012). Based on the foregoing, it can be predicted that the mathematical prior knowledge of students has a contribution to the achievement and enhancement of the High-Level Mathematical Thinking skills of student.

This study also considers differences in study programs from study subjects. This is because Integral Calculus is a compulsory subject, both in the Mathematics Education Study Program and the Mathematics Study Program. In addition, the characteristics of students from the Mathematics Education Study Program and Mathematics Study Program are different. For learning outcomes in the Mathematics Study Program, the emphasis is on mastering mathematical material and high-level mathematical thinking skills, while for the Mathematics Education Study Program, in addition to mastering mathematical material and high-level mathematical thinking skills, learning achievements also focus on educating, transferring knowledge, preparing, developing, developing and managing learning.

To enhance students' high-level mathematical thinking skills, an appropriate learning is needed. Wilson & Spears (2009) states that Brain-Based Learning is a comprehensive learning and based on brain's work, which suggests the brain learns naturally. Based on various studies that have been conducted, students who are given Brain-Based Learning show better results in their problem solving, reasoning, communication and mathematical connection skills than students who are given conventional learning (Ozden & Gultekin, 2008; Sugianti, 2010; Nurhadyani, 2010; Saleh, 2011; Seyihoglu & Kaptan, 2012; Damayanti & Sukestiyarno, 2014; Findasari, et al., 2014; Sukoco, 2014; and Nur, 2016). It is thus hoped that by using Brain-Based Learning, High-Level Mathematical Thinking Skills could be developed optimally.

In addition to using Brain-Based Learning, this study uses web media in learning. The use of web media which is part of the utilization of Information and Communication Technology (ICT) is intended to make learning more effective and efficient. In addition, the characteristics of the Calculus Course are abstract, uses a lot of graphics, drawings and widely applied in real life and other disciplines, these are a consideration for using web media in learning (Bogley, et al., 1996; Yushau, 2006).

Paris (2004) also revealed that students who received web-assisted learning had increased activity and positive attitudes towards learning, could study and be consulted outside of class hours. Various research findings also reveal that the use of ICTs in learning is effective enough to enhance High-Level Mathematical Thinking skills (Kulik, et al., 1991; Herrington & Oliver, 1999; Gundy, 2006; Nurlaelah, 2009; and Nuriadin, 2015). This combination of Brain-Based Learning and web media is hereinafter referred to as Web-assisted Brain-Based Learning. Web-assisted Brain-Based Learning consists of seven stages, namely (1) pre-exposure, (2) preparation,

(3) initiation and acquisition, (4) elaboration, (5) incubation and memory formation, (6) verification or beliefs checking, and (7) celebration and integration.

Based on this, the purpose of this study is to comprehensively analyze the achievement and enhancement of High-Level Mathematical Thinking Skills of students who get Web-assisted Brain-Based Learning compared to students who get conventional learning based on (a) overall; (b) mathematical prior knowledge; and (c) type of study program.

2. Method

This study used a quantitative method with a pretest-posttest control group design. The study population included all students in the mathematics department from one of the universities in Central Java. The sample was a group of students who take Integral Calculus subjects and they were students of Mathematics study programs and Mathematics Education study programs. For each study program, the sample choosed two classes randomly, the experimental class was taught using web-assisted brain-based learning, while the other class was taught using conventional learning as a control class. This research used various instruments. They were Mathematical Prior Knowledge Test, High-Level Mathematical Thinking Skills Test, and Observation sheet. Data were analyzed using t-test, t'-test, Mann-Whitney U test, and two ways ANOVA.

3. Result and Discussion

3.1. Mathematical prior knowledge

The Mathematical Prior Knowledge Test is used to find out the student's mathematical prior knowledge for material that is a prerequisite of the Integral Calculus course. The results of this Mathematical Prior Knowledge Test are used as a basis for classifying students according to their skills, namely students with high, medium and low ability types. The results of the mean and standard deviation calculation in total for group that get Web-Assisted Brain-Based Learning respectively are 19.85 and 3.89, while group that get conventional learning respectively are 19.95 and 4.80. When viewed from the study program, for Mathematics Education Study Program, group that get web-assisted Brain-Based Learning respectively are 20.19 and 4.28, while group that get conventional learning respectively are 20.26 and 5.45. As for Mathematics Study Program, group that get Web-Assisted Brain-Based Learning respectively are 19.44 and 3.40, while group that get conventional learning respectively are 19.62 and 4.04. The Ideal Score for Mathematical prior knowledge test was 31.

Furthermore, to find out that groups that get Web-Assisted Brain-Based Learning and groups that get conventional learning in each study program have equivalent mathematical prior knowledge conditions, students' mathematical prior knowledge scores in two groups in each study program are mean difference test. The results can be seen in Table 1.

Table 1. Statistical Test Results for Mathematical Prior Knowledge

Study Program	Learning Model	Normality test			Homogeneity Test			Mean Difference Test		
		n	sig	Result	F	sig	Result	t	$sig\ (1-tail)$	Result
Math Education	BL	42	0,806	Normal	3,217	0,077	Homogeneous	-0,067	0,947	Equal
	CV	42	0,781	Normal						
Math	BL	36	0,525	Normal	1,473	0,229	Homogeneous	-0,197	0,844	Equal
	CV	39	0,811	Normal						

From Table 1, it can be concluded that both groups in the same study program have an equivalent mean on mathematical prior knowledge. Furthermore, based on the scores obtained by the Mathematical Prior Knowledge Test, students in each group are divided into several ability categories, namely high, medium, and low. The distribution of research samples based on mathematical prior knowledge and types of study programs can be seen in Table 2 below.

Tabel 2. The Distribution of Research Samples

Skor MPK	BL			CV			Total
	Math. Ed	Math	Total	Math. Ed	Math	Total	
High	11	5	16	13	8	21	37
Medium	21	21	42	17	20	37	79
Low	10	10	20	12	11	23	43
Total	42	36	78	42	39	81	159

3.2. High-level mathematical thinking skills

The High-Level Mathematical Thinking Skills Data is obtained based on the High-Level Mathematical Thinking Skills Test score. Higher-Level Mathematical Thinking Skills after learning, in general it can be said that overall, the mean achievement and enhancement of Higher-Level Mathematical Thinking Skills of students who get Web-assisted Brain-Based Learning are higher than those who get conventional learning. Likewise, if viewed based on the types of students' mathematical prior knowledge (high, medium and low), the mean achievement and enhancement of High-Level Mathematical Thinking Skills of students who get Web-Assisted Brain-Based Learning is also higher than those who get conventional learning. It can be said that learning and mathematical prior knowledge of students have an influence on the achievement and enhancement of High-Level Mathematical Thinking skills.

To find out more about the differences in achievement and enhancement of High-Level Mathematical Thinking Skills of students who get Web-Assisted Brain-Based Learning with those who get conventional learning, an overall analysis is performed, based on the type of mathematical prior knowledge and the type of study program. The results of the statistical tests can be seen in Table 3 and Table 4.

Table 3. Result of Statistical Test Data Achievement of High-Level Mathematical Thinking Skills

Study Program	MPK	Learning Model	Normality test			Homogeneity Test			Mean Difference Test			
			n	*sig*	Result	*F*	*sig*	Result	*t*	*t'*	*sig (1 – tailed)*	Result
Math Education	High	BL	11	0.898	Normal	1.627	0.215	Homogeneous	2.151		0.025	Better
		CV	13	0.801	Normal							
	Medium	BL	21	0.437	Normal	7.825	0.008	Not Homogeneous		1.984	0.021	Better
		CV	17	0.887	Normal							
	Low	BL	10	0.938	Normal	3.831	0.044	Not-Homogeneous		1.993	0.022	Better
		CV	12	0.526	Normal							
	Total	BL	42	0.465	Normal	10.239	0.002	Not Homogeneous		2.511	0.008	Better
		CV	42	0.216	Normal							

Math	High	BL	5	0.925	Normal	0.387	0.547	Homogeneous	2.142		0.025	Better
		CV	8	0.839	Normal							
	Medium	BL	21	0.935	Normal	0.914	0.345	Homogeneous	5.384		0.000	Better
		CV	20	0.615	Normal							
	Low	BL	10	0.764	Normal	5.024	0.037	Not Homogeneous		3.951	0.001	Better
		CV	11	0.843	Normal							
	Total	BL	36	0.565	Normal	0.360	0.551	Homogeneous	6.563		0.000	Better
		CV	39	0.875	Normal							
Total		BL	78	0.384	Normal	5.520	0.000	Not Homogeneous		6.029	0.000	Better
		CV	81	0.420	Normal							

Table 4. Result of Statistical Test Data Enhancement of High-Level Mathematical Thinking Skills

Study Program	**MPK**	**Learning Model**	**Normality test**			**Homogeneity Test**			**Mean Difference Test**			
			n	***sig***	**Result**	***F***	***sig***	**Result**	***t***	***t'***	***sig (1 – tailed)***	**Result**
Math Education	High	BL	11	0.880	Normal	1.222	0.281	Homogeneous	2.145		0.018	Better
		CV	13	0.765	Normal							
	Medium	BL	21	0.370	Normal	9.249	0.004	Not Homogeneous		1.922	0.024	Better
		CV	17	0.694	Normal							
	Low	BL	10	0.989	Normal	0.623	0.440	Homogeneous	1.947		0.023	Better
		CV	12	0.953	Normal							
	Total	BL	42	0.378	Normal	8.015	0.006	Not Homog		2.315	0.012	Better

		CV	42	0.249	Normal			eneous				
Math	High	BL	5	0.851	Normal	0.177	0.682	Homogeneous	2.303		0.016	Better
		CV	8	0.807	Normal							
	Medium	BL	21	0.889	Normal	3.376	0.074	Homogeneous	2.908		0.003	Better
		CV	20	0.807	Normal							
	Low	BL	10	0.736	Normal	7.470	0.013	Not Homogeneous		4.243	0.001	Better
		CV	11	0.751	Normal							
	Total	BL	36	0.477	Normal	0.018	0.894	Homogeneous	6.592		0.000	Better
		CV	39	0.706	Normal							
Total		BL	78	0.315	Normal	10.658	0.001	Not Homogeneous		5.826	0.000	Better
		CV	81	0.602	Normal							

Based on Table 3 and Table 4, it can be concluded that the achievement and enhancement of high-level mathematical thinking skills of students who get Web-assisted Brain-Based Learning is higher than students who get conventional learning, both overall, based on mathematical prior knowledge and the type of study program .

To find out whether there is a mean difference data achievement of high-level mathematical thinking skills of students who get Web-assisted Brain-Based Learning based on the type of mathematical initial ability and the type of study program. Statistical testing is carried out, the results of which can be seen in Table 5.

Table 5. Result of One-way ANOVA Test Data Achievement of High-Level Mathematical Thinking Skills based on Type of Mathematical Prior Knowledge and Type of Study Program Students That Get Web-Assisted Brain-Based Learning

Category		Sum of Square	*df*	Mean Square	F	*Sig*
MPK	Between Group	276,676	2	138,338	4,155	0,019
	Within Group	2497,273	75	33,297		
Total		2773,949	77			
SP	Between Group	1,810	1	1,810	0,050	0,824
	Within Group	2772,139	76	36,476		
Total		2773,949	77			

Based on Table 5, it can be seen that there are significant differences in the mean achievement of students' High-Level Mathematical Thinking skills based on the type of mathematical prior

knowledge (high, medium, low). Another case is the mean enhancement of High-Level Mathematical Thinking Skills of students based on study programs (Mathematics Education, Mathematics) which do not show any significant differences.

To find out the mean achievement of High-Level Mathematical Thinking skills based on the type of mathematical prior knowledge of students who get Web-Assisted Brain-Based Learning have a significant different or not, a Post Hoc Test was conducted using Tamhane Test. Results of the Tamhane Test can be briefly seen in Table 6.

Table 6. Results of Tamhane Test Data Achievement of High-Level Mathematical Thinking Skillsbased on Type of Mathematical Prior KnowledgeStudents That Get Web-Asisted Brain-Based Learning

MPK (I)	MPK (J)	Mean Difference (I-J)	Sig	Result
High	Medium	2,616	0,323	Equal
	Low	5,538	0,048	Better
Medium	Low	2,921	0,312	Equal

Based on Table 6, it can be seen that the achievement of High-Level Mathematical Thinking skills between students who have high and medium mathematical prior knowledge given Web-Assisted Brain-Based Learning is equivalent, the achievement of High-Level Mathematical Thinking Skills between students who have medium and low mathematical prior knowledge given Web-Assisted Brain-Based Learning is equivalent, while the achievement of High-Level Mathematical Thinking Skills students who get Web-Assisted Brain-Based Learning among students who have high mathematical prior knowledge are better than achieving High-Level Mathematical Thinking Skills students who have low mathematical prior knowledge .

Furthermore, to find out whether there are differences in the average enhancement data of students' high-level mathematical thinking skills who get Web-Assisted Brain-Based Learning based on the type of mathematical prior knowledge and type of study program. Statistical testing is carried out, and it can be seen in Table 7.

Table 7. Result of One-way ANOVA Test Data Enhancement of High-Level Mathematical Thinking Skills based on Type of Mathematical Prior Knowledge and Type of Study Program Students That Get Web-Assisted Brain-Based Learning

Category		Sum of Square	df	Mean Square	F	Sig
MPK	Between Group	0,089	2	0,044	2,216	0,116
	Within Group	1,505	75	0,020		
Total			77			
SP	Between Group	0,000	1	0,000	0,020	0,889
	Within Group	1,594	76	0,021		
Total			77			

From Table 7 it can be seen that there is no significant difference in the mean enhancement of students' High-Level Mathematical Thinking skills based on the type of mathematical prior knowledge (high, medium, low) and the type of study program (Mathematics Education, Mathematics).

Based on the description above, it can be said that Web-Assisted Brain-Based Learning can make students with low mathematical prior knowledge gain a mean of achievement and enhancement in high-level mathematical thinking skills equivalent to students who have medium mathematical prior knowledge. Likewise students who have mathematical prior knowledge are those who get Web-Assisted Brain-Based Learning to get the mean achievement and enhancement in high-level mathematical thinking skills equivalent to students who have high mathematical prior knowledge.

This studys' findings revealed that in Mathematics Education Study Program students, the component of Higher-Level Mathematical Thinking skills that obtained the highest achievement was the mathematical communication component. Another case in the Mathematics Study Program, where the achievement of High-Level Mathematical Thinking Ability is a component of mathematical reasoning. This shows that students from the Mathematics Education Study Program have an advantage in communicating mathematically which will be useful in the world of work later on, given that students in the Mathematics Education Study Program are prospective teacher who must be able to communicate their knowledge to students. It is different with Mathematics Study Program students who develop mathematics a lot. Thus the mathematical reasoning component does support for the reason above. This finding is in line with the Higher Education Curriculum (2014) which, based on the Indonesian National Qualification Framework states that one of the minimum learning outcomes of the Mathematics Education Study Program is to transfer knowledge to students, as well as one of the minimum achievements The Mathematics Program is able to develop mathematical thinking, which starts from procedural/ computational understanding to a broad understanding including logical reasoning, generalization, and proof.

4. Conclusion

This study concludes that:

Achievement and Enhancement of High-Level Mathematical Thinking Skills students that get Web-Assisted Brain-Based Learning are higher than students that get conventional learning. Achievement and enhancement of High-Level Mathematical Thinking Abilities students that get Web-Assisted Brain-Based Learning as a whole are included in the high category, while the achievement and enhancement of High-Level Mathematical Thinking Skills students that get conventional learning as a whole are included in the medium category.

For each category of mathematical prior knowledge (high, medium, low) the achievement and enhancement of high-level mathematical thinking skills of students that get Web-Assisted Brain-Based Learning is higher than the students that get conventional learning. The mathematical prior knowledge factor has a significant influence on the achievement of High-Level Mathematical Thinking Skills of students that get Web-Assisted Brain-Based Learning, but does not have a significant effect on enhancing the High-Level Mathematical Thinking Skills of students that get Web-Assisted Brain-Based Learning.

Achievement and Enhancement of High-Level Mathematical Thinking skills of students that get Web-Assisted Brain-Based Learning is higher than students that get conventional learning, this happens both in the Mathematics and Mathematics Education Study Program. This type of study program does not have a significant effect on the achievement and enhancement of High-Level Mathematical Thinking Skills for students that get Web-Assisted Brain-Based Learning.

Recommendation

Based on the conclusions of this study, recommendations that can be given are as follows.

1. Implementation of Web-Assisted Brain-Based Learning requires a relatively longer time compared to conventional learning, so it is recommended to unify the sixth step, incubation and memory formation and the seventh step, namely verification. The integration of these two steps can be done through a package of practice questions that begin with relatively easy questions first and then continue with difficult questions to verify student understanding.
2. Lecturers should pay attention to students' mathematical prior knowledge before learning, both on Web-Assisted Brain-Based Learning and conventional learning. If students do not understand the mathematical prior knowledge material, lecturers should strengthen it first.

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This is because the mathematical prior knowledge of students influencing the learning outcomes.

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