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Enhancing Mathematical Reasoning: the effects of web-assisted Brain-Based Learning

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Abstract. The purpose of this study was to analyze the improvement of mathematical reasoning abilities comprehensively. This research is a quantitative study. The respondents of this research were students who take the Integral Calculus course at a university in Semarang. This study used a random class method to determine two classes of study samples. One class treated by Web Assisted Brain-Based Learning (BBLW) and another class treated by conventional learning. The results of the study showed that the mathematical reasoning ability of students who get Brain-Based Learning assisted by the web is better than that of students who get conventional learning based on their initial mathematical abilities.

1. Introduction

Mathematical reasoning is an essential aspect of doing mathematics. By equipping students with good mathematical reasoning, students are expected to be able to use it to solve various problems faced either when they are still students or after graduation later. However, proof as part of the reasoning is a mathematical process that is considered difficult by students [1]. The results of preliminary research conducted on students who took the Integral Calculus Course also gave the conclusion that students still have difficulty in providing explanations with facts and relationships, estimating answers and solutions, and providing evidence.

Efforts to improve mathematical reasoning abilities need to pay attention to students' initial mathematical abilities. This is because the mathematical structure is systematic. The concepts that have been possessed by students are a prerequisite of the concepts to be learned. Students will connect the new knowledge they obtain with their fundamental knowledge [2]. Based on the fact analysis, it can be predicted that the Student's Early Mathematical Capability has contributed to the improvement of students' mathematical reasoning abilities.

To be able to improve students' mathematical reasoning abilities, appropriate learning is needed. Brain-Based Learning is learning that is synchronized with the workings of the brain that are designed naturally for learning. This learning is focused on creating optimal conditions for the creation of natural and student-centered learning [3]

Brain-Based Learning is a comprehensive and foundational study on the work of the brain, which suggests the brain learns naturally. Brain-Based Learning now becomes a standard platform for many reforms in learning [4]. Based on various studies that have been done, students who are given Brain-Based Learning show better results in mathematical reasoning than that of students who given conventional learning [5–10]. A learning environment based on Brain-Based Learning has a beneficial influence on the students' retention and provides support for higher-level learning [11]. In addition, the use of Brain-Based Learning as a framework to train teachers assisted students in gaining a good

achievement in mathematics course [12]. Thus it is expected that by using Brain-Based Learning, mathematical reasoning abilities can also develop optimally.

The web media used in this research to assist Brain-Based Learning. The use of web media, which is part of the use of Information and Communication Technology (ICT), is intended to make learning more effective and efficient. Besides that, the characteristics of the Calculus are abstract, using many graphics and images, and are widely applied in real life [13]. The web-based media can be used to provide graphical representation and symbolic expression of Calculus concepts, which is important for assisting students' understanding [14]. Students who receive web-assisted learning experience increased activity and show a positive attitude towards learning can study outside of school hours and can consult outside of school hours. Various research findings also reveal that the use of ICT in learning is sufficient enough to improve students' mathematical reasoning abilities [15,16]. This combination of Brain-Based Learning and web media is henceforth referred to as Web Assisted Brain-Based Learning.

In Web Assisted Brain-Based Learning, students not only learn through websites but with face-to-face meetings in class as well. The purpose of this meeting is for students to interact with the environment, lecturers, and students. Besides, lecturers can treat students as unique individuals. As is well known, good teaching is to consider students as unique individuals with different levels of intelligence. This corresponds to that Brain-Based Learning can facilitate all students with different levels of intelligence summarized in the same learning style [3].

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 checking of beliefs, and (7) celebrations and integration.

The first stage in The Web Assisted Brain-Based Learning, which is called the pre-exposure stage, is done by giving a program that contains a concept map, learning objectives, and several perceptual questions on a website or websites. This is so that students have prepared themselves before the lecture takes place so that learning can be more optimal. For the next stage, the lecturer gives a problem and a series of tasks, through shows on the web, to be discussed in groups. The results of similar discussions were then presented at the front by group representatives who were to be given responses by all students and lecturers. Then each student is given practice questions on the web in two types (easy and challenging to do individually) with music. The final part of this learning is drawing conclusions made by students together with the lecturers, followed by celebrations. Student activities in the stages of Web Assisted Brain-Based Learning make students able to construct their knowledge. So it is expected that by following these stages, students' reasoning abilities can increase.

Based on the description above, this study aims to analyze the application of Web-Based Learning (BBLW) comprehensively to improve student reasoning abilities.

2. Methods

The purpose of this study was to comprehensively analyze the improvement of mathematical reasoning abilities through Web Assisted Brain-Based Learning. This study uses a quantitative method. The respondents of this study were all students of the Mathematics Education Study Program at a university in Central Java. The samples from this study were two classes of mathematics education who took the Integral Calculus course, which was taken randomly. One class received learning using Web Assisted Brain-Based Learning and another class, as a control class, using conventional learning. Furthermore, this research used a test of mathematical reasoning abilities, observation sheets, and interview guides. The data were analyzed using a t-test.

3. Results and Discussion

3.1. Initial Mathematical Ability

The Mathematical Initial Ability Test is used to determine the students' initial mathematical ability to the material, which is a prerequisite of the Integral Calculus course. The results of the Initial Mathematical Ability Test were used as a basis for classifying students according to their abilities, namely students with high, medium, and low abilities. Calculation of mean ($\bar{x}$) and standard deviation (s) is done to describe the quality of students' initial mathematical abilities. The value of $\bar{x}$ for

Conventional Method (Cv) and Web Assisted Brain-Based Learning (BBLW) is 20.26, respectively, while the values of s are 4.28 and 5.45.

First, the students' initial mathematical ability scores in the two groups were tested for differences. This was used to find out that the two groups: the group that received BBLW instruction and the group that received conventional instruction had identical initial conditions.

Before the mean difference test, the normality test and the variance homogeneity of the two groups of data were carried out first. The Kolmogorov-Smirnov Z test was used in the normality test, while the F Test was used to check the homogeneity. The results of normality are in Table 1, while the results of a homogeneity test are in Table 2.

Table 1. Data Normality Test Results of Initial Mathematical Ability

Statistics	BBLW	Cv
N	42	42
Kolmogorov-Smirnov Z	0.641	0.657
Sig	0.806	0.781
H_0	accepted	accepted

Note. H_0: Data is normally distributed, H_1: Data is not normally distributed

Table 2. Homogeneity Test Results Data Variance of Initial Mathematical Ability

Statistics	Result
F	3.217
df1	1
df2	82
Sig	0.077
H_0	accepted

Note. H_0: The variance of the two data groups is homogeneous, H_1: The variance of the two groups of data is not homogeneous

Since the initial mathematical capability data is assumed to be normal and homogeneous, the average difference test is performed with the t-test. The hypothesis testing criteria used are if the Sig value is more than 0.05, then H_0 is accepted, and in other cases, H_0 is rejected.

Table 3. Data Average Difference Test Results of Initial Mathematical Ability

Statistics	BBLW	Cv
$\underline{x}$	20.19	20.26
t	-0.067	
Sig (2−tailed)	0.947	
H_0	accepted	

Note. H_0: There was no difference in the mean between the two groups, H_1: There were differences in the mean between the two groups

Table 3 shows that the two groups have equivalent mathematical initial abilities. Furthermore, based on the Initial Mathematical Ability Test scores obtained, students in each group were divided into several ability categories: high, medium, and low. The distribution of research samples based on initial mathematical abilities and types of study programs can be seen in Table 4.

Table 4. Distribution of Research Samples based on Early Mathematical Capabilities and Types of Study Programs

Score	BBLW	Cv	Total
High	11	13	37
Middle	21	17	79
Low	10	12	43
Total	42	42	159

3.2. Results of mathematical reasoning ability data analysis

Data on the Mathematical reasoning ability of students is obtained based on the scores of the Mathematical Reasoning Ability Test (both pre-test and post-test). Based on the descriptive statistics Mathematical reasoning ability, the average achievement and improvement of mathematical reasoning abilities of students of BBLW are higher than students who obtain conventional learning both as a whole and in terms of their initial abilities. Table 5 shows the result.

Table 5. Results of mathematical reasoning ability data analysis

Category			BBLW				Conv				Total			
Dept	Math Ability	Stat	Pretest	Postest	$<g>$	n	Pretes	Postes	$<g>$	n	Pretest	Postest	$<g>$	n
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Math Education	High	$\bar{x}$	4.909	15.727	0.842	11	5.154	14.615	0.739	13	5.042	15.125	0.786	24
		s	4.230	3.036	0.210		3.313	3.948	0.310		3.677	3.530	0.269	
	Mid	$\bar{x}$	2.333	14.667	0.790	21	3.294	13.353	0.664	17	2.763	14.079	0.733	38
		s	2.008	3.088	0.190		1.961	3.639	0.289		2.019	3.364	0.244	
	Low	$\bar{x}$	3.400	12.600	0.635	10	1.250	11.583	0.618	12	2.227	12.045	0.626	22
		s	2.366	5.296	0.355		1.138	4.814	0.285		2.069	4.942	0.311	
	Sub Total	$\bar{x}$	3.262	14.452	0.767	42	3.286	13.238	0.674	42	3.274	13.845	0.720	84
		s	2.955	3.788	0.249		2.717	4.166	0.291		2.821	4.004	0.274	

3.3. The Results of Data Analysis of Student Mathematical Reasoning Pre-test Ability

The Mathematical reasoning ability pre-test is carried out before the lecture on Integral Calculus takes place. This pre-test aims to get a picture of the condition of students' mathematical reasoning abilities before attending the lecture both in groups that get Web Assisted Brain-Based Learning and groups that get conventional learning. Therefore, as a result of the data on the pre-test score of mathematical thinking ability obtained, the mean difference test was performed. Before the mean difference test, the normality test and the variance homogeneity of the two groups of data were carried out.

The results of the normality test of the pretest showed that the data are normally distributed (Table 6). Meanwhile, the test of variances homogeneity (Table 7) showed that the data of pretest are homogeneous.

Table 6. The results of Normality Test for Data of Mathematical Reasoning Pretest

Statistics	BBLW	Cv
N	42	42
Kolmogorov-Smirnov Z	0.793	0.767
Sig	0.556	0.599
H_0	Accepted	Accepted

Tabel 7. The results of the test of variances homogeneity

Statistics	Result
F	1.059
$df1$	1
$df2$	82
Sig	0.307
H_0	Accepted

The difference in the mean pretest data mathematical reasoning ability of the two groups were tested by t-test. Table 8 shows that there is no significant difference between the mean pretest data in the group that received BBLW instruction and the conventional instruction group. Thus, the students' mathematical reasoning abilities before being given treatment are similar.

Tabel 8. The results of t-test

Statistics	Result
t	-0.982
$Sig\ (2-tailed)$	0.329
H_0	Accepted

Note. H_0: There was no difference in the mean between the two groups, H_1: There were differences in the mean between the two groups.

3.4. Achievement of Students' Mathematical Reasoning Abilities based on Learning

The results of the normality test of the mathematical reasoning ability showed that the data are normally distributed (Table 9), and the test of variances homogeneity (Table 10) showed that the data of pretest are homogeneous.

Tabel 9. Data Normality Test Results Achievement Mathematical reasoning ability based on Learning

Statistics	BBLW	Cv
N	42	42
Kolmogorov-Smirnov Z	1.252	1.206
Sig	0.087	0.109
H_0	Accepted	Accepted

Tabel 10. The results of the test of variances homogeneity

Statistics	Result
F	0.933
$df1$	1
$df2$	82
Sig	0.337
H_0	Accepted

Furthermore, the t-test was used to find out the difference between the achievement of students' mathematical reasoning abilities with BBLW and students with conventional instruction. The results can be summarized in Table 11. The sig value for the test of the difference in the average data of mathematical reasoning achievement is less than 0.05, so H_0 is rejected. This means that the achievement of mathematical reasoning of students who enter the BBLW class is higher than the achievement of students who enter using conventional learning [9,10,12].

Tabel 11. Mean Difference Test Results Achievement Data Mathematical reasoning abilities based on learning

Statistics	Result
t	2.029
$Sig\ (1-tailed)$	0.048
H_0	rejected

3.5. Achievement of Students' mathematical reasoning abilities based on Learning and Mathematical Early Ability

The results of the normality test for the achievement of data Mathematical reasoning abilities of students based on learning and initial mathematical abilities are summarized in Table 12.

Table 12. Normality Test Results of Data Achievement of mathematical reasoning abilities based on Learning and Early Mathematical Capabilities

Initial Mathematical Capabilities	Instruction	N	Kolmogorov-Smirnov Z	Sig	H0
High	BBLW	11	1.059	0.212	accepted
	Cv	13	0.665	0.768	accepted
Mid	BBLW	21	0.858	0.453	accepted
	Cv	17	0.811	0.526	accepted
Low	BBLW	10	0.727	0.666	accepted
	Cv	12	0.709	0.696	accepted
Total	BBLW	42	1.252	0.087	accepted
	Cv	42	1.206	0.109	accepted

Note. H_0: Data is normally distributed, H_1: Data is not normally distributed

The sig value for the normality test of all achievement data Mathematical reasoning ability based on learning and the type of initial mathematical ability is more than 0.05, so H_0 is accepted. That is, all achievement data mathematical reasoning abilities are normally distributed.

Because all data is normally distributed, then after the normality test is followed by testing the homogeneity of achievement data Mathematical reasoning ability based on learning and initial mathematical ability types, the results of the test of homogeneity of variance can be seen in Table 13.

Table 13. Homogeneity Test Results Data Variance Achievement of Mathematical Reasoning Ability based on Learning and Types of Early Mathematical Capabilities

Initial Mathematical Capabilities		F	df1	df2	Sig	H_0
High	BBLW CV	0.603	1	22	0.446	accepted
Mid	BBLW CV	2.395	1	36	0.148	accepted
Low	BBLW CV	0.430	1	18	0.496	accepted
Total	BBLW CV	0.933	1	82	0.337	accepted

Note. H_0: The variance of the two groups of data is homogeneous, H_1: The variance of the two groups of data is not homogeneous

Table13 shows that the value of the sig test for the variance homogeneity of the data achieves mathematical reasoning abilities for all initial mathematical abilities and overall is more than 0.05, so H_0 is accepted. This means that both groups of data achievement mathematical reasoning ability for all initial and overall mathematical abilities have a homogeneous variance.

Table 14. Mean Difference Test Results Data Achievement of Level Mathematical Thinking Ability based on Learning, Types of Initial Mathematical Capabilities and Types of Study Programs

Initial Mathematical Capabilities		t	Sig (1−tailed)	H_0
High	BBLW Cv	2.151	0.048	rejected
Mid	BBLW Cv	1.984	0.044	rejected
Low	BBLW Cv	1.993	0.049	rejected
Total	BBLW	2.511	0.048	rejected

Note. H_0: There was no difference in the mean between the two groups, H1: The mean KPM of the BBLW group was higher than the Cv group

Table 14 shows that the sig value for the test of the average difference in achievement data Mathematical reasoning ability for students with high, medium, and low initial, as well as overall mathematical abilities, are all less than 0.05, meaning H_0 is rejected. So, the achievement of mathematical reasoning abilities of students who get Web Assisted Brain-Based Learning is higher than students who get conventional learning in terms of their initial and overall mathematical abilities [15,16].

Furthermore, to find out whether there are differences in the average data achievement of students' mathematical reasoning abilities of students who get Web Assisted Brain-Based Learning, a normality test and a data variance homogeneity test are conducted first. The normality test shows that the data achievement of students' mathematical reasoning abilities based on learning and types of initial mathematical abilities are normally distributed. The results of the test of variance homogeneity of achievement data Students' mathematical reasoning abilities carried out using the F Test (in brief) can be seen in Table 15.

Table 15 shows that the achievement data of students' mathematical reasoning abilities based on their initial mathematical abilities have a sig value of less than 0.05, so H_0 is accepted. This means that achievement data Mathematical reasoning abilities of students based on their initial mathematical abilities have a non-homogeneous variance.

Table 15. Homogeneity Test Results Data Variance Achievement of Reasoning Ability based on Types of Early Mathematical Capabilities of Students Who Get Web-Assisted Brain-Based Learning

Statistics	Initial Mathematics Ability
F	12.505
df1	2
df2	39
Sig	0.000
H_0	rejected

Note. H_0: The variance of the two data groups is homogeneous, H1: The variance of the two groups of data is not homogeneous.

Next, to find out whether there are differences in average achievement data of the mathematical reasoning abilities of students who get Web Assisted Brain-Based Learning, based on the types of initial mathematical abilities, the one-way ANOVA test was used. The results of the one-way ANOVA test can be seen briefly in Table 16.

Table 16. One-way ANOVA Test Results

		Sum of Squares	df	Mean Sum Of Squares	F	Sig
Math Ability	Intergroup	430.726	2	215.363	3.226	0.051
	In Group	2603.679	39	66.761		
Total		3034.405	41			

Table 16 shows that the sig value of achievement data mathematical reasoning ability based on the type of initial mathematical ability of students who get Web Assisted Brain-Based Learning is more than 0.05, so H_0 is accepted. This means that there is no significant difference in the achievement average of students' mathematical reasoning abilities based on the type of initial mathematical abilities (high, medium, low).

4. Conclusion

Based on the results of the calculation of the difference test analysis on the achievement of students' mathematical reasoning ability, it can be concluded that the achievement of mathematical reasoning abilities of students who get Web Assisted Brain-Based Learning is higher than students who get conventional learning both overall and in terms of their initial mathematical abilities.

As if viewed based on the type of initial mathematical abilities, it can be concluded that there is no difference in the achievement of mathematical reasoning abilities of students who get Web Assisted Brain-Based Learning for all types of initial mathematical abilities (high, medium, low).

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