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Comparison of the Advantages of Brain-Based Learning and Scientific in Terms of Student's Mathematical Literacy and Self-Efficacy

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Abstract

The purpose of the research was to compare the benefits of scientific models and brain-based learning (BBL) with reference to junior high school students' mathematical literacy and self-efficacy. This kind of study is a quasi-experiment. In order to understand more about the system of linear equations with two variables, the study was carried out between July and August of 2024. All Class VIII pupils from a public junior high school in Yogyakarta made up the study's population. Two-class samples were chosen at random. Mathematical literacy test questions and a self-efficacy questionnaire were the tools used. Both tools are trustworthy and legitimate—an independent sample T-test was conducted after the data analysis method using Manova with T2 Hotelling test statistics. The sample data must originate from a multivariate normal distributed population with the same variance-covariance matrix, according to the Manova assumption. The findings of the research, which used α=5%, demonstrated that BBL outperformed the scientific method in terms of average self-efficacy and mathematical literacy scores as well as when examined per indicator of both variables.

Keywords: Brain-Based Learning, Scientific, Mathematical Literacy, *Self-Efficacy*

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INTRODUCTION

Education in the 21st century requires teachers to implement learning models that focus on delivering material, developing students' critical thinking, creative, and literacy skills, and emphasising exploration of the learning process and cooperation in solving problems. (Kim et al., 2019). One of the biggest challenges in learning mathematics is creating an engaging learning environment that facilitates students' deep understanding of abstract concepts. In such a context, innovative learning approaches are essential to implement (Vale & Barbosa, 2023).

Appropriate methods, learning models, and learning innovations must support improving students' abilities to achieve the desired learning objectives (Dewi, 2018). An appropriate learning model must back these learning goals to accomplish these goals. (Maulana et al., 2023). One innovative and exciting learning model appropriate for achieving the desired learning objectives is brain-based learning, oriented to how the brain works (Riskiningtyas & Wangid, 2019). According to Wijayanti et al. (2021), brain-based learning (BBL) is learning that is scientifically intended to be in line with how the brain functions. In the classroom, educators must be able to provide instruction that inspires students' creativity (Sukardi et al., 2021). Unlike conventional learning, BBL focuses on meaningful learning beyond memorisation. BBL is a term that describes how to apply theories related to how the brain works to help children maximise learning. According to

Handayani et al. (2020), In line with how the brain functions during learning, the BBL model places a strong focus on the joy and passion of learning.

Pre-exposure, (2) preparation, (3) initiation and acquisition, (4) elaboration, (5) incubation and memory encoding, (6) verification and confidence checking, and (7) celebration and integration are the phases of the Brain-Based Learning paradigm, according to Jensen (2008). The Brain-Based Learning model offers a number of benefits, such as (1) establishing an enjoyable learning atmosphere that tests students' critical thinking abilities, (2) establishing an engaging and significant learning environment for students, (3) Increasing student engagement, (4) Optimizing brain function; (5) Increasing comprehension and retention; (6) Facilitating meaningful learning; (7) Supporting emotional balance; and (8) Spurring creativity and problem-solving.

So far, math teachers in the field more often apply the scientific approach than BBL. The scientific approach encourages students' active participation in developing their understanding and mathematical abilities through critical thinking, exploration, and discovery (Putra et al., 2021). The scientific approach is designed to familiarise students with thinking, behaving, and working with a scientific foundation. It has stages: observation (Observation), questioning, gathering information / trying, reasoning, and communicating. (Lestari & Sutawan, 2024). This approach has the advantages of (1) improving student learning outcomes, (2) enhancing pupils' ability to approach issues methodically, (3) establishing an environment for learning where kids believe that education is essential, (4) training students in expressing and communicating ideas, and (5) developing students' character and emotional intelligence. (Kerimbayev et al., 2023).

Students should acquire mathematical skills by implementing BBL and the scientific approach. One of the mathematical abilities that is anticipated to be obtained through mathematics learning is Mathematical Literacy Ability (Stacey & Turner, 2015). Mathematical Literacy is an integral part of shaping 21st-century skills (Hasmiwati & Widjajanti, 2020; Rizki & Priatna, 2019). This is due to the increasing complexity and difficulty of everyday problems. A person has strong mathematical literacy if he can solve and comprehend mathematical problems and successfully analyse, reason, and communicate mathematical knowledge and abilities. (Maslihah et al., 2020)

However, the Mathematical Literacy of Indonesian students is still a problem. Dewi & Widjajanti, 2022; Ahyan et al., 2021). Based on PISA data in 2018 and 2022, Indonesia's score decreased by 13 points from 379 to 366, and there was a decrease of 106 points from the international average score with a ranking of 72 out of 78 countries in 2018 and 70 out of 81 countries in 2022 (OECD, 2023). According to some study findings, pupils' mathematical literacy abilities still need to be improved (Ariati et al., 2022). Their skills are still not optimal, leading to low results (Hamdiyanti et al., 2024). One factor thought to be causing students' low Mathematical Literacy Skills is their difficulty facing problems involving complex situations because they are only accustomed to solving simple problems (Masfingati et al., 2022).

Teachers must include students' psychological characteristics, such as self-efficacy, in addition to their mathematical literacy abilities. A person's perceived confidence in their capacity to plan and execute activities to produce outcomes under certain circumstances is known as self-efficacy (Bandura, 2009). When studying mathematics, one ability that must be cultivated is self-efficacy (Zakariya, 2022). High self-efficacy students often make use of their abilities to achieve results by optimal expectations (Saks, 2024).

Research results in Simamora et al. (2018) When it comes to handling arithmetic issues, pupils who have poor self-efficacy often comprehend the problem less because they do not write down what is known and asked. There are some mistakes in making plans and not making conclusions, and some problems are not given the results of their solutions.

Students with low self-efficacy can lack the courage to face complex tasks and give up easily if faced with obstacles (Basileo et al., 2024). Low self-efficacy in students will significantly affect the learning process. More specifically, the research results of Kurniawati and Mahmudi (2019) state that self-efficacy is very influential on students' Mathematical Literacy Skills. Students' mathematical literacy skills will improve with their level of self-efficacy (Nisa & Arliani, 2023). Additionally, students' self-efficacy was evaluated by PISA 2022, and the findings indicated that Indonesian students' self-efficacy remained below the average of other participating nations (OECD, 2023). Therefore, self-efficacy is very important to be improved.

According to several research, the BBL approach improves student learning outcomes (Jazuli et al., 2019). They concluded that students' mathematical literacy skills improved when they learned to utilise BBL. One effective teaching strategy for raising pupils' mathematical literacy is to use the BBL model. The phases of BBL learning, which serve as markers of mathematical literacy, demonstrate this. When it comes to teaching mathematics, instructors still hardly ever adopt the BBL approach. The lecture style is still used by some math professors, which makes pupils more likely to be passive. Even though students' brain weariness during learning might result in less-than-ideal learning results, few math instructors focus on the brain's ability to function throughout learning. The Scientific Approach has also been shown to significantly improve student learning results, much like BBL (Lagoudakis et al., 2022).

Some studies have also compared these two approaches. However, previous studies have not explicitly compared BBL and the Scientific Approach regarding Mathematical Literacy and Self-efficacy of junior high school students, especially in learning System of Linear Equations of Two Variables (SPLDV) material. Compared to the BBL model, the Scientific Approach is a more popular approach among teachers at school; so far, many teachers have implemented mathematics learning using the Scientific Approach, according to the recommendations of Curriculum 2013. The benefits of the Scientific Approach over BBL are shown by some study findings, such as the opinion of (Kerimbayev et al., 2023). However, theoretically, based on the steps in learning, researchers suspect that BBL is superior to the scientific approach in improving students' Mathematical Literacy and Self-efficacy. An empirical test is needed to prove this superiority. Therefore, this study compared BBL's benefits and the scientific method regarding students' Mathematical Literacy and Self-efficacy.

METHODS

Study groups created for educational purposes are used in this quasi-experiment. The chosen class is divided into two groups: one that receives therapy using a scientific technique and the other that receives treatment using brain-based learning. This study, which focused on the SPLDV, was carried out in a public junior high school in the city of Yogyakarta during the odd semester of the 2024–2025 academic year (July–August).

This study used a Nonequivalent (Pre-test and Post-test) Control-Group Design as its research design. Creswell (2023). The study's procedures included: (1) choosing two classes at random to participate in the experiments; (2) administering a prescale and pre-test to each class; (3) using the Brain-Based Learning model on one class and the Scientific Approach to the other class; (4) giving a questionnaire (Postscale) and Post-test to both classes after the second learning is implemented; (5) analysing the data; (6) concluding the research results.

The instruments used were Mathematical Literacy Ability test questions, *a Self-efficacy questionnaire, and a* learning implementation observation sheet. The questions to

measure students' literacy skills consist of 4 description questions using three indicators, namely Formulate, Employ, and Interpret, with the context of the questions, namely personal, occupational, societal, and scientific. Twenty statement questions with five Likert scale response options strongly agree (SS), agree (S), uncertain (RR), disagree (TS), and strongly disagree (STS) that contain both positive and negative statements utilising six indicators make up the tool used to measure students' self-efficacy. There are three dimensions, namely magnitude, generality, and strength. Both instruments were declared valid by three expert lecturers of Mathematics Education at Yogyakarta State University. Furthermore, construct validity was carried out for the self-efficacy instrument using factor analysis after fulfilling the requirements with the Kaiser Mayer-Olkin (KMO) test, which obtained a KMO value of 0.557 > 0.50. As for the reliability results of the Mathematical Literacy Ability Pre-tes and Self-efficacy questionnaire, respectively, 0.801 and 0.887 Cronbach's Alpha scores are more significant than 0.6. Therefore, it may be said that both instruments are trustworthy. The lattice of Mathematical Literacy questions is presented in Table 1 below.

Pre-test and post-test results on students' mathematical literacy skills, as well as prescale-postscale self-efficacy, were analysed in this research. Analysis of Pre-test and prescale data is used to describe the initial conditions of the sample class groups. At the same time, the analysis of Post-test and Post-scale data is used to compare the advantages of the BBL model and the Scientific Method in relation to junior high school pupils' self-efficacy and mathematical literacy.

RESULTS & DISCUSSION

Results

Data description of Mathematical Literacy Ability and Self-efficacy of BBL and Scientific Approach classes before and after learning is presented in the Table 1.

Table 1. Data of Mathematical Literacy test results of students who are given Brain-Based Learning and Scientific Approach

No.	Data	*Brain-Based Learning*		Scientific Approach	
		Pre-test	*Post-test*	*Pre-test*	*Post-test*
1.	Mean	45,09	71,78	40,34	63,19
2.	Ideal Minimum Value	0	0	0	0
3.	Ideal Maximum Value	100	100	100	100
4.	Minimum Student Score	10	40	23	40
5.	Maximum Student Score	73	88	71	90
6.	Standard Deviation	17,355	12,393	10,554	14,097

Table 1 shows that the average pre-test scores for Mathematical Literacy Skills in both classes are almost the same; however, hypothesis testing is carried out to ensure that the averages can be considered equal. Likewise, the class treated with BBL had a higher average mathematical literacy ability than the class treated with the scientific approach, according to the average post-test results of the two courses. However, further hypothesis testing is needed to determine whether BBL is superior to the scientific approach regarding mathematical literacy ability.

Furthermore, Table 2 presents the results of the achievement of each indicator of students' Mathematical Literacy Ability obtained from two classes.

Table 2. Achievement of each indicator of Mathematical Literacy Ability

No.	Indicators	Description	*Brain-Based Learning*		Scientific Approach	
			Pre-test	*Post-test*	*Pre-test*	*Post-test*
1.	***Formulate*** Construct or create mathematical models of problems in diverse content and contexts.	Means	17,32	29,44	18,80	27,52
		% achievement	52,12%	88,41%	56,41%	82,64%
2.	***Employ*** Apply problem-solving strategies using concepts, facts, procedures, and reasoning.	Means	15,62	24,09	14,30	21,12
		% achievement	46,86%	72,34%	42,90%	63,42%
3.	***Interpret*** Interpret the meaning of mathematical solutions from various content and real-world contexts.	Means	12,10	18,25	7,24	14,55
		% achievement	36,30%	54,80%	21,72%	43,69%
	Overall mean		45,09	71,78	40,34	63,19

Table 2 demonstrates that the class that used the BBL model outperformed the class that used the scientific method in terms of both average and percentage of accomplishment for each measure of mathematical literacy ability.

There are three levels of mathematical literacy: high, medium, and poor. Class grouping findings utilising the scientific method and the Brain-Based Learning model are shown in Table 3.

Table 3. Frequency and Percentage of Achievement of Mathematical Literacy Skills with Brain-Based Learning Model and Scientific Approach

Value Interval	*Brain-Based Learning*				Scientific Approach				Categories
	Pre-test		*Post-test*		*Pre-test*		*Post-test*		
	f	%	f	%	f	%	f	%	
$76 < x \leq 100$	0	0%	11	34%	0	0%	6	19%	High
$66 < x \leq 75$	2	6%	12	38%	1	3%	9	28%	Medium
$0 < x \leq 65$	30	94%	9	28%	31	97%	17	53%	Low

Table 3 shows that the percentage of students with low Mathematical Literacy Skills was extensive before the implementation of learning in both classes (BBL and Scientific). However, after the implementation of learning, the percentage appears to be reduced. On the other hand, for students with Mathematical Literacy Skills classified as medium and high before the implementation of learning, the percentage increases at the end.

Self-efficacy questionnaire data was obtained from administering questionnaires before (prescale) and after treatment (postscale) in classes given the BBL model and those given the scientific approach. In general, students in each class have fairly good self-efficacy. This can be seen from the data description in Table 4.

Table 4. Self-efficacy questionnaire data of students who are given learning Brain-Based Learning and Scientific Approach

No.	Indicators	*Brain-Based Learning*		Scientific Approach	
		Pre-scale	*Post-scale*	*Pre-scale*	*Post-scale*
1.	Mean	64,22	71,72	62,50	66,97
2.	Ideal Minimum Value	20	20	20	20
3.	Ideal Maximum Value	100	100	100	100
4.	Minimum Student Score	40	60	49	45
5.	Maximum Student Score	79	85	80	84
6.	Standard Deviation	7,682	7,031	7,287	11,015

Although Table 4 indicates that the two classes' average prescale scores are almost identical, hypothesis testing is done to make sure that the two classes' average scores are the same. Likewise, the average postscale score of both classes shows that the average score in the BBL treatment is more improved than in the class with the Scientific Approach treatment. However, further hypothesis testing is needed related to both. Furthermore, Table 5 presents the results of the achievement of each indicator of student self-efficacy obtained from two classes.

Table 5. Achievement of each indicator of Mathematical Literacy Ability

Indicators	Description	*Brain-Based Learning*		Scientific Approach	
		Pre-test	*Post-test*	*Pre-test*	*Post-test*
Magnitude					
1. Confidence in facing difficulties in learning math	Means	12,38	13,94	12,31	13,66
	% achievement	74%	84%	74%	82%
2. Confidence in solving math problems/tasks with different levels of difficulty	Means	12,44	13,94	11,97	12,78
	% achievement	75%	84%	72%	77%
Generality					
3. Confidence in solving a wide variety of math problems	Means	6,41	6,91	6,47	6,34
	% achievement	38%	41%	39%	38%
4. Confidence in dealing with varied situations or conditions in learning mathematics	Means	9,78	10,69	9,50	11,13
	% achievement	59%	64%	57%	67%
Strength					
5. Confidence in one's effort and perseverance in learning mathematics	Means	12,10	18,25	7,24	14,55
	% achievement	36,30%	54,80%	21,72%	43,69%
6. Confidence in achieving achievement or goals in learning mathematics	Means	13,94	14,63	12,94	13,81
	% achievement	84%	88%	78%	83%

Table 5 shows that the increase in self-efficacy scores is also reflected in the average achievement value of both prescale and postscale scores for each indicator.

Furthermore, the self-efficacy data are grouped into five categories: high, high, medium, low, and very low. The grouping results are presented in Table 6.

Table 6. Frequency and Percentage of Self-efficacy Achievement of students in classes with Brain-Based Learning model and Scientific Approach

Value Interval	*Brain-Based Learning*				Scientific Approach				Categories
	Pre-test		*Post-test*		*Pre-test*		*Post-test*		
	f	%	f	%	f	%	f	%	
$80 < x \leq 100$	0	0%	5	16%	2	6%	3	9%	Very High
$67 < x \leq 80$	12	38%	20	63%	7	22%	16	50%	High
$54 < x \leq 67$	17	53%	7	22%	20	63%	10	31%	Medium
$41 < x \leq 54$	2	6%	0	0%	3	9%	3	9%	Low
$0 < x \leq 75$	1	3%	0	0%	0	0%	0	0%	Very Low

Table 6 shows that most students had self-efficacy in the medium category before learning; after the treatment, the highest percentage was in the high category.

The initial conditions of the two classes were equal in terms of the average mathematical literacy ability and self-efficacy of students. This was done in order to compare the benefits of scientific models and brain-based learning in terms of junior high school students' mathematical literacy and self-efficacy. Hypothesis testing of the final data was done since the findings of the first conditions' hypothesis testing indicated that the average Mathematical Literacy Ability and Self-efficacy of students from both courses could be regarded as being the same. The following is the first test of the Covariance Variance Matrix's similarity and the Multivariate Normality assumptions.

Multivariate Normality Assumption Test and Variance Covariance Matrix Homogeneity Assumption Test

IBM SPSS Statistics 24 was used to perform the multivariate normality test by creating a scatter plot between the chi-square and the squared distance (Mahalanobis distance). The Multivariate Normality Test yielded the following findings.

Table 7. Multivariate Assumption Test Results of Pre-tes-Prescale and Results of Homogeneity Test of Covariance Variance Matrix

	Group	Correlation Coefficient	R Table	Sig.
Pretes-Prescale	BBL	0,978	0,3494	0,068
	Scientific	0,967	0,3494	
Posttest-Postscale	BBL	0,988	0,3494	0,108
	Scientific	0,967	0,3494	

Table 7 indicates that the starting and end data for both classes originate from a multivariate regularly distributed population, and the covariance variance matrix of the two groups in the population may be regarded as the same because, as Table 7 shows, the significance value for the homogeneity test before treatment is 0.068 and after treatment is 0.108.

Multivariate Hypothesis Test of Pretest-Prescale and Posttest-Postscale Data Before Treatment and After Treatment

Decision criteria: H_0 Is rejected if the value of sig.<0,05, H_0 Is accepted if the value of sig. ≥ 0,05

Table 8. Multivariate Test Results of Pretes-Prescale and Posttest-Postscale Data

	Data	T^2	F	p-value
Hottelling's T^2	Pretes-Prescale	0,032	0,987	0,378
	Posttest-Postscale	0,133	4,048	0,022

According to Table 8, the initial data's p-value (Pre-tes-prescale) is 0.378, more than 0.05, and H_0 is approved. This indicates that the two classes' starting abilities for both variables are the same. For testing the final result (Pre-tes-prescale), the p-value of 0.022 is less than 0.05, so H_0 is rejected. This means that using 5% alpha, it can be concluded that there are different averages between the two classes. The Independent Sample T-test was conducted to clarify whether the difference is only in one or both variables.

Independent Sample T-test Hypothesis Test of Mathematical Literacy Ability and Self-efficacy

Decision criteria: H_0 is rejected if the value of sig.<0,05, H_0 is accepted if the value of sig. ≥ 0,05

Table 9. Results of Independent Sample T-test Hypothesis Test of Mathematical Literacy Ability and Self-efficacy

Dependent Variable	t	df	p-value
Mathematical Literacy	2,608	1,99897	0,011
Self-efficacy	2,056	1,99897	0,044

According to Table 9, the class that received the Scientific Approach had a lower average Mathematical Literacy Ability than the Brain-Based Learning class. Similarly, when it came to the self-efficacy component, students who received brain-based learning had higher average self-efficacy than the class that received the scientific method.

Discussion

The results of the research showed that, in terms of average and percentage of success for each mathematical literacy metric, the class that used the BBL model did better than the class that employed the Scientific Approach. These results are in line with research by Lestari and Sutawan (2024) that found that the BBL paradigm enhanced students' mathematical literacy abilities. The BBL approach, which emphasises learning without compulsion, creating a pleasant environment, and maximising students' brain capacities, is inextricably linked to this growth.

The Formulation indicator, which involves gathering or developing mathematical models of issues in a variety of settings and topics, is the Mathematical Literacy Ability indication that has increased the most in both the BBL and the Scientific Approach classes. In the Brain-Based Learning class, this indicator increased by the most, by 12.07, while in the Scientific Approach class, it increased by 8.72. These findings suggest that the Scientific Approach and the BBL model may be used to improve students' capacity to construct, compose, or generate mathematical models.

The Mathematical Literacy Ability indicator with the lowest average is the Interpret indicator. The *Interpret* indicator relates to students' ability to interpret the meaning of mathematical solutions from various content and real-world contexts. These findings are consistent with those of Maslihah et al. (2020), who found that students' abilities can be classified as high when it comes to creating mathematical scenarios but low when it comes to applying mathematical concepts, facts, procedures, and reasoning. As for the interpreting process, namely interpreting, applying, and evaluating mathematical results, students' abilities can be categorised as very low. Therefore, the process needs to be improved again.

The BBL model outperforms the Scientific Approach in terms of the average Mathematical Literacy Ability and Self-efficacy of junior high school students in a Yogyakarta school on the material System of Linear Equations of Two Variables (SPLDV), according to the results of hypothesis testing. This superiority is believed to be supported by the fact that students are more involved in the BBL learning process than they are in the Scientific method. According to Jensen (2008), the BBL model may help students understand the relevance of mathematics in real-world circumstances by making the learning environment enjoyable, testing their critical thinking abilities, and creating engaging and relevant learning settings for them to apply mathematical ideas.

Even though this research demonstrates that the BBL Approach outperforms the Scientific Approach in raising junior high school students' average levels of mathematical literacy and self-efficacy, math instructors still need to take a number of factors into account. First, the advantages of brain-based learning lie in the stages of learning that are based on how the brain works, such as facilitating attention, emotional involvement, and connections to previous experiences (Jensen, 2008). Suppose teachers are not able to make the learning stages active and exciting. In that case, the increase in Mathematical Literacy and Self-efficacy in both groups of students may not be significant. Second, for BBL to provide maximum benefits for students, teachers must provide relevant and exciting learning resources, such as learner worksheets (LKPD) designed to support deep thinking and understanding.

CONCLUSION

In terms of the average Mathematical Literacy Ability and Self-efficacy of grade VIII junior high school students in a public junior high school in Yogyakarta on the material of the System of Linear Equations of Two Variables (SPLDV), BBL is superior to the Scientific Approach, according to the results of hypothesis testing using $\alpha = 5\%$. The superiority is viewed from both variables' overall average and achievements per indicator.

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