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# Brain-based Learning and Critical Thinking Ability on Physics Learning Outcomes

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## *Abstrak*

*PISA 2018 melaporkan hasil belajar fisika siswa Indonesia yang rendah. Kurangnya keterlibatan siswa dalam pembelajaran diduga menjadi penyebab masalah ini. Pilihan pembelajaran berbasis otak (BBL) bisa menjadi salah satu alternatif untuk mengatasi masalah ini. Penelitian ini bertujuan untuk menganalisis perbedaan hasil belajar fisika antara siswa dengan model pembelajaran BBL dan konvensional serta pengaruh interaksi antara model pembelajaran dan keterampilan berpikir kritis terhadap hasil belajar fisika. Jenis penelitian ini yaitu quasi-experimental dengan desain post-test only control group design. Populasi penelitian ini adalah seluruh siswa kelas X yang berjumlah 120 orang. Pemilihan sampel menggunakan random assignment. Metode yang digunakan dalam mengumpulkan data yaitu observasu dan tes. Instrumen yang digunakan untuk mengumpulkan data yaitu lembar tes. Teknik analisis data dalam penelitian ini menggunakan analisis deskriptif dan analisis varians dua arah (ANOVA) serta telah melalui uji asumsi. Hasil penelitian yaitu terdapat perbedaan yang signifikan hasil belajar fisika antara siswa dengan pembelajaran BBL dan siswa dengan pembelajaran konvensional (Sig.0,000<0,05) dan tidak terdapat pengaruh interaksi yang signifikan antara model pembelajaran dan keterampilan berpikir kritis terhadap hasil belajar fisika (Sig.0.690 >0,05). Disimpulkan terdapat pengaruh yang signifikan model pembelajaran BBL terhadap hasil belajar fisika dan tidak terdapat pengaruh interaksi yang signifikan antara model pembelajaran BBL dan keterampilan berpikir kritis terhadap hasil belajar fisika.*

***Kata kunci:*** *Pembelajaran Berbasis Otak, Hasil Pembelajaran, Kemampuan Berpikir Kritis*

## Abstract

PISA 2018 reported low physical learning outcomes for Indonesian students. Lack of student involvement in learning is one of the causes of this problem. Brain-based learning options (BBL) can be an alternative to overcome this problem. This study analyzes the differences in physics learning outcomes between students with BBL and conventional learning models and the effect of interactions between learning models and critical thinking skills on physics learning outcomes. This type of research is quasi-experimental with a post-test-only control group design. The population of this study was all students of class X who found 120 people. Sample selection using random assignment. The methods used in collecting data are observation and tests. The instrument used to collect data is a test sheet. The data analysis technique in this study used descriptive analysis and two-way analysis of variance (ANOVA) and had been through assumption testing. The results showed that there was a significant difference in physics learning outcomes between students with BBL learning and students with conventional learning (Sig. 0.000 <0.05), and there was no significant interaction effect between learning models and critical thinking skills on physics learning outcomes (Sig. 0.690). >0.05). It was concluded that the BBL learning model had a significant effect on physics learning outcomes. There was no significant interaction between the BBL learning model and critical thinking skills on physics learning outcomes.

**Keywords:** Brain-Based Learning, Learning Outcomes, Critical Thinking Skills

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## 1. INTRODUCTION

Education as a means of support in preparing students for the next stage becomes the foundation for improving the quality of human resources (Palavan et al., 2016; Sari et al., 2020; Wang & Kuo, 2019). Various efforts have been made by the government through the relevant ministries the realization of the national goal, namely the intellectual life of the nation. One of the efforts in question is to make changes and improvements to the curriculum

(Abitolkha et al., 2020; Buchori Muslim, 2020). Education is inseparable from the curriculum as the basic framework of the educational process itself. Until now, in Indonesia, the latest curriculum is the revised 2013 curriculum. The rationale for the 2013 revised curriculum is that knowledge cannot be transferred completely from teacher to student, but students construct their knowledge accompanied by the teacher (Haqiqi, 2019; Mulyadin, 2016). The 2013 curriculum is adjusted to improve students' skills, attitudes, and knowledge (Fitriani et al., 2020; Mega et al., 2015). In addition, the revised 2013 curriculum also views students as educational subjects who can move, process, construct, and use their knowledge (Fitri et al., 2017; Sofyan, 2019). This rationale is in line with constructivist learning and student-centered learning.

Basically, science is a science that includes processes, products, and attitudes (Kusumayuni & Agung, 2021; Zeren Özer & Güngör, 2017). As a branch of science, physics can also be viewed as the same as the nature of science (Astalini et al., 2018; Bancong & Song, 2018). Science as a process prioritizes the process of how to obtain knowledge, especially natural science. Science as a product emphasizes the results obtained in scientific activities, both concepts, and equations. Science as an attitude emphasizes more efforts to equip, train, or instill positive values in students. The 2013 curriculum, also emphasizes student-centered learning (Fitriani et al., 2020; Setiawan et al., 2020). Student-centered learning causes students to be more active in the learning process while the teacher only acts as a facilitator (Czajka & McConnell, 2019; Keiler, 2018). This will result in more meaningful learning for the students themselves because they can construct their knowledge. This will lead to an increase in students' critical (Devi et al., 2016; Seruni et al., 2020).

Based on the efforts that have been made, the quality of science education in Indonesia should be improved. The scientific ability of students in Indonesia is still relatively low. Based on the results of the 2018 Program for International Student Achievement (PISA) test and evaluation, the average achievement score of Indonesian students in the field of science was ranked 74 out of 79 countries evaluated by the Organization for Cooperation and Development (OECD) (Narut & Supradi, 2019; Nugrahanto & Zuchdi, 2019). This rating has decreased from year to year. The results of this report also show a decline in the ranking of students' science achievement in Indonesia. This decline indicates that there is a wrong process in education in Indonesia that occurs systematically and comprehensively. Without any follow-up, this will certainly become a bad culture of education in Indonesia which makes the quality of education output, especially the ability of science in Indonesia, decreases (Lestari, 2020; Wahyuni et al., 2020).

The concept of curriculum development that leads to student activity and a critical attitude along with other efforts should produce optimal learning outputs (Mugisha & Mugimu, 2015; Nasir, 2020). However, without being accompanied by understanding and application as well as the right perspective, efforts that are aimed at increasing learning output will only become a formal means. In the process, the majority of teachers are only oriented toward achieving material achievement targets but have not developed the competencies of students to the fullest (Baharuddin, 2021; Halawa, 2021; Putera & Shofiah, 2021). In addition, learning still takes place in one direction and students rarely see real phenomena or media related to the material and the lack of use of learning aids or media. Based on interviews with class X IPA students at SMAN 1 Komodo stated that the learning model applied was still using the conventional model with the stages of orientation, presentation, structured exercises, guiding exercises, and independent exercises which caused students to become passive because they were fully controlled by the teacher. This weakens students' interest and motivation because learning is monotonous and teacher-centered which weakens students' scientific attitude.

Based on the problems described above, the right alternative for this problem is to improve the learning process by actively involving students both in the learning process and building their cognitive structure according to the constructivist paradigm adopted by the 2013 curriculum (Fitriani et al., 2020; Wachidi et al., 2020; Wardoyo et al., 2020). The learning model has an important role along with the ability to think critically about the results. student learning (Dewi et al., 2020; Fitra Surya, 2017; Mari & Gumel, 2015). The learning model used must be able to involve students actively (student-centered) and be able to optimally utilize the work functions of the brain (Alfiani & Sopiyani, 2014; Wang & Kuo, 2019). Optimal utilization of brain function will lead to an increase in students' critical thinking skills and active learning that comes from the students themselves.

The learning model that fits this problem is brain-based learning. Brain-based learning requires teachers to understand how the brain works so that teachers can design lessons that can maximize the use of students' brains when learning (Prastuti et al., 2019; Solihat et al., 2017). This model is student center in that it uses all parts of the brain and recognizes that not all students learn in the same way, thereby freeing students to build their knowledge of diverse and contextual learning situations (Nurasiah et al., 2022; Silvana & Wibisono, 2016). Through the steps of the pre-exposure stage which help the brain build a better conceptual map, the preparatory stage that motivate students' curiosity (A. AAdiansha & Sani, 2021; Adi, 2019). The initiation and acquisition stage where students make connections and communicate with each other. The elaboration stage is where students associate learning. The incubation and inserting memory stage where students repeat and refresh the learning they have received. The verification and belief checking stage which is a form of control again regarding students' understanding during the learning process and the celebration and integration stage which is a motivational generation and instills a love of learning in students will produce an atmosphere or learning environment that stimulates students' thinking skills, presents students in a pleasant learning environment and creates an active and meaningful learning atmosphere for students (Al-ruely & Hamed, 2018; Delawati et al., 2019). So that this will train students' critical thinking skills which leads to improving student learning outcomes.

Based on the description above, researchers are interested in raising the topic of the influence of brain-based learning models and critical thinking skills on students' physics learning outcomes. There is strong evidence regarding the effect of the brain-based learning model on student learning outcomes. Based on research shows that there is a positive and significant influence between the brain-based learning model and student achievement (Uzezi & Jonah, 2017). The same thing was also revealed which stated that students' critical thinking skills taught by brain-based learning assisted by mind maps were superior to students taught by brain-based learning alone (Mukaromah et al., 2020). Other research also stated that there was an increase in learning achievement with the brain-based learning model (Shabatat & Al-Tarawneh, 2016). In addition, critical thinking skills also contribute to improving student learning outcomes (Devi et al., 2016; Mulyanto et al., 2020; Polat & Aydın, 2020). Belum adanya kajian mengenai Brain-based Learning dan Kemampuan Berpikir Kritis terhadap Hasil Belajar Fisika Kelas X SMA. Tujuan penelitian ini yaitu menganalisis pengaruh Brain-based Learning dan Kemampuan Berpikir Kritis terhadap Hasil Belajar Fisika Kelas X SMA. Diharapkan Brain-based Learning dan Kemampuan Berpikir Kritis dapat mempengaruhi hasil belajar siswa.

## 2. METHODS

This study was designed as quasi-experimental research with a post-test-only control group design. This study involves three variables, namely the independent variable is the learning model, the moderator variable is the ability to think critically and the dependent variable is the student's physics learning outcomes. The population in this study were all students of class X at SMA Negeri 1 Komodo which consisted of 120 students and were distributed into 4 classes, namely X IPA 1, X IPA 2, X IPA 3, and X IPA 4. All classes in the population were homogeneously distributed. based on the results of the equivalence test with an F score of 0.633 and p = 0.595 (p > 0.05). This means that students' abilities in physics are considered equivalent for class X IPA 1 to Class X IPA 4. The sample selection in this study used the random assignment technique. The researcher chose 2 classes as samples from the 4 existing classes. The two selected classes are drawn again to determine the treatment to be given to each class. The experimental group, namely X IPA 3, received the treatment of Brain Base Learning, and the control group, namely X IPA 4, received the conventional learning treatment. The two selected sample classes were subjected to a 2 x 2 factorial analysis design with a factor of critical thinking ability.

The data collected in this study include scores of critical thinking skills and scores of physics learning outcomes. The data collection instrument used in this study was an essay test for critical thinking skills consisting of 10 questions and an objective test for physics learning outcomes consisting of 30 questions with Newton's law of gravity material. The range of scores for each item of critical thinking ability is 0-4 and for the question of learning physics learning outcomes if the correct answer is given a score of 1 and if incorrect is given a score of 0. The test reliability value for the critical thinking ability test is 0.69 with a high classification and the test reliability value for the test learning outcomes are 1.02 with a very high classification so both instruments are reliable for measuring critical thinking skills and learning outcomes. The data analysis technique in this study used descriptive analysis and two-way analysis of variance (ANOVA) and had gone through the assumption test, namely the normality test, homogeneity test, and linearity test. As a follow-up to the ANOVA test, a Tukey HSD follow-up test was performed.

## 3. RESULTS AND DISCUSSION

### Result

The general description of student learning outcomes describes the distribution of variance, average value and standard deviation based on the learning model, and the interaction between learning models and critical thinking skills. Based on data analysis shows that based on the learning model, the group of students who studied with the brain-based learning (A1) learning model obtained an average value of physics learning outcomes of 86.56 with a standard deviation of 8.05. This gain was higher than the group of students who studied with the conventional learning model (A2) which obtained an average value of 67.22 physics learning outcomes with a standard deviation of 7.74. Based on the interaction between the learning model and critical thinking skills, the group of students who studied with the brain-based learning model who had high critical thinking skills (A1B1) obtained an average score of 93.33 for physics learning outcomes with a standard deviation of 4.18. The group of students who studied with the brain-based learning model who had low critical thinking skills (A1B2) obtained an average score of 79.78 for physics learning outcomes, with a standard deviation of 4.27. The group of students who study with conventional learning models who have high critical thinking skills (A2B1) obtained an average value of physics learning outcomes of 73.56 with a standard deviation of 4.27. The group of students who studied with conventional learning models who had low critical thinking skills (A2B2) obtained an average score of 60.89 for physics learning outcomes with a standard deviation of 4.45. Based on the results of the descriptive analysis, it can be explained that the percentage gain in the application of each model is as shown in Table 1.

**Table 1**. Percentage of Differences in Learning Outcomes Based on Descriptive Statistics

| Variable | Percentage Difference Mean Value (%) |
|---|---|
| A1 : A2 | 22.3% |
| A1B1 : A1B2 | 14.5% |
| A1B1 : A2B1 | 21.2% |
| A1B1 : A2B2 | 34.8% |
| A1B2 : A2B1 | 7.8% |
| A1B2 : A2B2 | 23.7% |
| A2B1 : A2B2 | 17.2% |

Table 1 shows the physics learning outcomes of students who follow the brain-based learning (A1) learning model have an average score of 22.3% higher than the physics learning outcomes of students who follow the conventional learning model (A). The physics learning outcomes of students who follow the brain-based learning model in the category of high critical thinking skills (A1B1) have a higher average score of 14.5% compared to the physics learning outcomes of students who follow the brain-based learning model in the category of critical thinking abilities. low (A1B1). Physics learning outcomes of students who follow the brain-based learning model of high critical thinking ability category (A1B1) have a higher average score of 21.2% compared to physics learning outcomes of students who follow conventional learning models of high critical thinking ability category (A2B1). Physics learning outcomes of students who follow the brain-based learning model of high critical thinking ability category (A1B1) have a higher average score of 34.8% compared to physics learning outcomes of students who follow conventional learning models of low critical thinking ability category (A2B2). Physics learning outcomes of students who follow the brain-based learning model of low critical thinking ability category (A1B2) have a higher average value of 7.8% compared to physics learning outcomes of students who follow conventional learning models of high critical thinking ability category (A2B1). Physics learning outcomes of students who follow the brain-based learning model of low critical thinking ability category (A1B2) have a higher average value of 23.7% compared to physics learning outcomes of students who follow conventional learning models of low critical thinking ability category (A2B2). Physics learning outcomes of students who follow the conventional learning model in the category of high critical thinking ability (A2B1) have a higher average value of 17.2% compared to the physics learning outcomes of students who take conventional learning in the category of low critical thinking abilities (A2B2).

The data were analyzed using SPSS 16.0 for Windows. The first assumption test is the normality test of the data using the Kolmogorov-Smirnov Test. The summary of the results of the normality test is normally distributed ($p>0.05$). The second assumption test is the homogeneity test of variance using Levene's Test of Equality Variance. A summary of the homogeneity test results shows that the variance between groups was homogeneous ($p>0.05$). The results of the analysis of the variance of the two paths of students' critical thinking skills based on the differences in models and the interaction between the models and critical thinking skills are shown in Table 2.

**Table 2.** Results of Two Paths ANOVA Analysis of Physics Learning Outcomes

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
|---|---|---|---|---|---|---|---|---|
| *Corrected Model* | 8,188.230 | 3 | 2,729.410 | 148.222 | 0.000 | 0.888 | 444.665 | 1.000 |

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
|---|---|---|---|---|---|---|---|---|
| *Intercept* | 354,715.099 | 1 | 354,715.099 | 1.926E4 | 0.000 | 0.997 | 19,262.947 | 1.000 |
| *Model* | 5,606.667 | 1 | 5,606.667 | 304.472 | 0.000 | 0.845 | 304.472 | 1.000 |
| *Critical thinking* | 2,578.606 | 1 | 2,578.606 | 140.032 | 0.000 | 0.714 | 140.032 | 1.000 |
| *Model Critical thinking* | 2.957 | 1 | 2,957 | 0,161 | 0,690 | 0,003 | 0,161 | 0,068 |
| *Error* | 1,031.205 | 56 | 18,414 | | | | | |
| *Total* | 363,934.534 | 60 | | | | | | |
| *Corrected Total* | 9,219.435 | 59 | | | | | | |

Table 2 shows the first hypothesis, namely that there are differences in physics learning outcomes between students who learn by applying the brain-based learning model and students who learn by applying conventional learning models to Class X students of SMA Negeri 1 Komodo in the 2019/2020 academic year. The results of the two-way ANOVA analysis in Table 2 show that the model variable has a value of p = 0.000 (p. <0.05), this means that the null hypothesis is rejected and the alternative hypothesis is accepted or there is a significant difference in physics learning outcomes between students who follow brain-based learning and students who follow conventional learning. The second hypothesis is that there is an interaction effect between the brain-based learning model and students' critical thinking skills on the physics learning outcomes of class X SMA Negeri 1 Komodo for the 2019/2020 academic year. The results of the analysis in Table 2 and the graph in Figure 1 show that the interaction variable between the learning model and critical thinking skills has a p-value = 0.690 (p > 0.05) and the graph is parallel, this means that the null hypothesis is accepted and the alternative hypothesis is rejected or there is no significant interaction effect between the brain-based learning model and critical thinking on students' physics learning outcomes.

The results of the Tukey HSD test at a significance level of 5% which is an advanced test (Post Hoc Tests) to determine the best interaction effect in improving student physics learning outcomes. The summary of the results of the Tukey HSD analysis can be seen in Table 3.

**Table 3.** Tukey HSD Test Results Summary

| Variable | Average | Variable | Average | Mean difference | P Value | Description |
|---|---|---|---|---|---|---|
| A1B1 | 93.33 | A1B2 | 79.78 | 13.55 | 0.000 | Signifikan |
| A1B1 | 93.33 | A2B1 | 73.56 | 19.77 | 0.000 | Signifikan |
| A1B1 | 93.33 | A2B2 | 60.89 | 32.44 | 0.000 | Signifikan |
| A1B2 | 79.78 | A2B1 | 73.56 | 6.22 | 0.001 | Signifikan |
| A1B2 | 79.78 | A2B2 | 60.89 | 18.89 | 0.000 | Signifikan |
| A2B1 | 73.56 | A2B2 | 60.89 | 12.67 | 0.000 | Signifikan |

Table 3 shows the learning outcomes of brain-based learning with high critical thinking skills (A1B1), the results of learning physics are 13.55 (14.5%) higher than the physics learning outcomes of students who take part in brain-based learning with low critical thinking skills (A1B2 ) with p-value = 0.0001 ($p < 0.05$). The same thing also happened to brain-based learning with high critical thinking skills (A1B1), the physics learning outcomes were 32.44 (32.8%) higher than the physics learning outcomes of students who took conventional learning with low critical thinking skills (A2B2) with p-value = 0.0001 ($p < 0.05$). This means that the physics learning outcomes of students who take brain-based learning with high critical thinking skills further improve students' physics learning outcomes because they provide the highest average value for physics learning outcomes and students whose critical thinking skills are low but are taught using the brain model. -based learning still has better physics learning outcomes compared to students who are given conventional learning even though their critical thinking skills are high.

**Discussion**

The implementation of learning by applying the brain-based learning model cannot be separated from the principles that form the basis for its implementation in the learning process. So the results of this study prove that there is a significant difference in the physics learning outcomes of students who take part in learning by applying the brain-based learning model with students who take part in conventional learning. Physics learning outcomes of students who take part in learning by applying the brain-based learning model are 32.8% higher than the results of learning physics of students who follow conventional learning. The significant difference in physics learning outcomes between students with brain-based learning models and students who follow conventional learning is caused by differences in treatment in the use of learning models. The same thing was also reported which stated that there was a significant and positive effect between brain-based models learning on learning outcomes and students' understanding of concepts (Duman, 2010; Putri et al., 2019; Saadah & Isnaeni, 2020). The results of this study are also supported by previous research which stated that there was an increase in student achievement when taught with a brain-based learning model (Kristanto et al., 2021; Shabatat & Al-Tarawneh, 2016).

An increase in conceptual understanding and student achievement in previous studies occurs because the brain-based learning model places more emphasis on students as the center of learning. Students have the flexibility to associate new understandings with what they already have to build mature concepts. In the process, students will learn by using all parts of their brains to be able to build their own, and contextual knowledge (Mutakinati et al., 2018; Nordlöf et al., 2019; Walton & Rusznyak, 2020). The application of brain-based learning models can also improve student learning outcomes through students' mathematical critical thinking skills (Duman, 2010; Kristanto et al., 2021; Solihat et al., 2017). The application of the brain-based learning model can stimulate students' critical and creative thinking processes (Duman, 2010; Putri et al., 2019). This means that the implementation of a brain-based learning model that is synergized with students' high critical thinking skills will certainly be able to optimize the student's physics learning outcomes. Students' critical thinking skills have an important role in improving physics learning outcomes because, with their critical thinking skills, students will be able to analyze or evaluate the information they get from the learning process they follow (Devi et al., 2016; Mutakinati & Anwari, 2018; Suardana et al., 2018). Thus, indirectly students will be able to better understand and understand the meaning of the learning carried out.

The application of the brain-based learning model is a suitable condition for students to improve their understanding of concepts. In the brain-based learning model, students will be actively involved in learning activities and indirectly increase students' intrinsic motivation. Brain-based learning models can also improve students' critical thinking skills (Kristanto et al., 2021; Saadah & Isnaeni, 2020). This learning also has implications for students' critical thinking skills. The effectiveness of the course of learning in improving students' critical thinking skills can be helped by considering, paying attention to, and including students' cognitive styles (Polat & Aydın, 2020; Seruni et al., 2020). Although the application of the model effects students' critical thinking skills, the interaction between the two does not have a significant effect. This result is also supported by research that also states that there is no interaction between the brain-based learning model and critical thinking skills (Mukaromah et al., 2020). The existence of other factors that affect critical thinking skills causes the interaction between the brain-based learning model and critical thinking skills to be insignificant or non-existent. The initial ability factor is one of the factors that affect students' critical thinking skills (Mukaromah et al., 2020).

This research is limited to the relationship between the independent variables, namely the learning model, and critical thinking skills on the dependent variable, namely learning outcomes. There is no interaction between the brain-based learning model and critical thinking skills because students with high critical thinking skills applied to any learning model will obtain superior learning outcomes, this is because internal factors, namely motivation and willingness to learn are high, besides their initial abilities have been well conceptualized. Students who have higher learning readiness (interest and self-efficacy) will always be superior or have high critical thinking skills if any learning model is applied and vice versa students with low learning readiness (interest in learning and self-efficacy) will have the ability to think lower critical when applied to any learning model. However, this study has research limitations in examining other factors that can affect critical thinking skills and student learning outcomes, such as initial ability, self-efficacy, and interest in learning.

## 4. CONCLUSION

The brain-based learning model tends to be better than the conventional model because it involves students directly in the thinking process and actively associates learning. In addition, the absence of an interaction effect between the brain-based learning model and critical thinking skills on student learning outcomes means that this model is suitable for improving student learning outcomes, whether applied to students with high or low critical thinking skills. For physics teachers as an effort to improve students' physics learning outcomes, teachers should apply a student-centered learning model that does not burden the brain's performance too much, and can even optimize students' brain performance such as the brain-based learning model.

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