The Role of Brain-Based Learning in Training Students' Critical Thinking Skills

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Sections Info	ABSTRACT
	Objective: This research aims to determine the role of brain-based learning in training students' critical thinking skills. **Method:** The research method used is a review article from 20 main scientific articles obtained from Google Scholar, Google, and Science Direct online with the keywords brain-based learning and critical thinking skills. **Results:** The results show that brain-based learning can be applied to gain critical thinking skills in mathematics and natural science material compared to conventional learning. Brain-based learning notes how the brain processes and interprets information after processing. A learning method that aligns with how the brain functions naturally will help students become more adept at critical thinking. **Novelty:** One of the most challenging issues of the 20th century is the improvement of information technology and the environment. Building quality human resources is a strategic and critical function of high-quality education. Today's students need to learn how to think critically.

INTRODUCTION

Educators tend to place more emphasis on content in most of the learning they do rather than sharpening students' thinking skills. Educators claim to have taught students about 'thinking skills', indirectly or implicitly, when conveying the subject's content. However, the effectiveness of teaching thinking skills in this way is doubtful because students generally do not understand the thinking skills in question (Güner & Erbay, 2021; Huang et al., 2022; Kavenuke et al., 2020; Mursid et al., 2022; Sumarni & Kadarwati, 2020). Everyone needs high-level thinking skills to face every problem well. One form of high-level thinking ability is critical thinking ability.

Critical thinking skills must be given to students to present students' thoughts and understanding of something. Critical thinking skills are among the high-level thinking skills promoted in the current era (Nabella et al., 2024). Training students' abilities in critical thinking are very much accommodated in the independent curriculum (Kusmaharti & Yustitia, 2022; Madrazo & Dio, 2020; Sarwanto et al., 2021; Thorndahl & Stentoft, 2020; Utari & Afendi, 2022). In the independent curriculum, students are trained to think for themselves about the knowledge in their immediate lives and not only refer to the context and thoughts inherited from the teacher.

Critical Thinking is one of the high-level thinking skills that students must have because, apart from the demands of the 2013 curriculum, this essential thinking skill can be used by students to solve problems in their daily lives. Therefore, Ennis (1996) states that critical Thinking is a process of determining what to do and believe. Facione (2018) further noted that one of the characteristics of a critical thinker is the skill to regulate one's knowledge. Based on this point of view, critical thinking skills are essential to learn. Critical Thinking is straightforward, namely the skill of analyzing and evaluating

information. Critical thinkers create ideas, acquire and evaluate pertinent data, employ abstract concepts, think critically, keep an open mind, and interact with people in an effective manner (Bağ & Gürsoy, 2021; Dekker, 2020; Itmeizeh et al., 2020; Palavan, 2020; Tathahira, 2020). Necessary thinking skills are the processes and abilities involved in making decisions rationally. According to researchers, people were facing a problem based on this solution, which is to apply a Brain-Based Learning (BBL) model.

The BBL model applies techniques grounded in concepts derived from an awareness of the brain. BBL aims to change learning from memorization to meaningful learning. To be able to achieve this goal, three interactive elements are needed, namely 1) emotional conditioning (emotional conditioning to make it fun), 2) experiential learning (learning with student involvement), and 3) personal meaning (internalization of learning to make it more meaningful). The BBL model can direct students to learn optimally by optimizing the potential function of the left and right brain (Lutfillah et al., 2022). This model consists of 7 steps: pre-exposure, preparation, initiation and acquisition, elaboration, incubation and memory organization, verification or checking, and celebration and integration (Mubasyira et al., 2021; Murniati et al., 2023; Susriyati et al., 2023; Wulansari & Suarni, 2020; zakiah et al., 2022). Thus, to enhance students' critical thinking ability, the learning design is implemented in the learning process in this study. A learning approach that aligns with how the brain functions will help pupils develop the critical thinking skills they need.

This research was also motivated by several studies by researchers, namely Khoeriyah et al. (2019), who stated that the BBL model affected students' creative thinking abilities. This influence is proven by the hypothesis test results, which obtained a significant value. (2-Tailed) (0.00) < significance level value (0.05). The gain in creative thinking ability in the experimental class was higher than in the control class. This is proven by the average normalized gain value in the practical class, which is superior to the control class. The normalized gain of the experimental class is in the medium category, while the control class is in the low category. Diani et al. (2019) stated that the BBL learning model influences gain students' critical thinking ability regarding static fluids. This can be seen from the average score of students using the BBL learning model, which is higher than the intermediate critical thinking ability test results of students using the conventional model. Widyantari et al. (2020) stated that the BBL model influences high school students' necessary thinking abilities in physics.

To train students' critical thinking skills can be done in various ways. However, in this research, students can be taught critical thinking by applying brain-based learning, especially in physics subjects. This is a new factor that is trying to be researched. Based on the description above, research needs to be carried out to determine the role of BBL in training students' critical thinking skills. Research to determine the effect of training critical thinking skills using brain-based learning can contribute to considering teachers who want to design innovative learning.

RESEARCH METHOD
This scientific article was written using a review article system sourced from 20 scientific articles used as references. Data sources were collected through Google Scholar, Google, and Science Direct online with the keywords "Brain-Based Learning" and "Critical Thinking Skills." The research collected comes from national and international journals. The article review method is a systematic review that consists of identification, screening, full review, data extraction, analysis, and conclusions on the

results of relevant previous research (Anggraeni et al., 2023; Prahani et al., 2023; Saphira, 2022; Suliyanah et al., 2021; Suprapto et al., 2021).
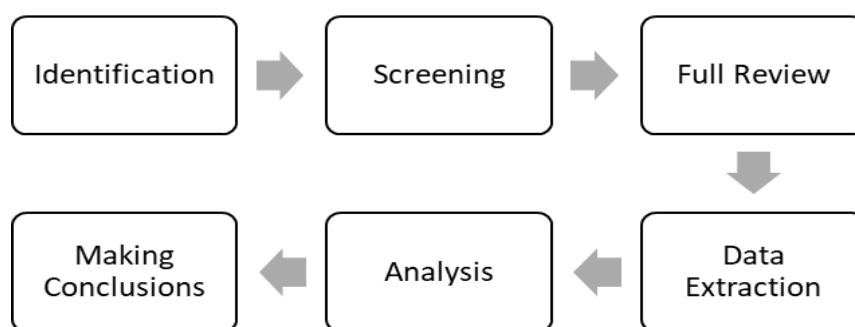

Figure 1. Research flow (Petyko et al., 2021).

1. Step 1
   At this stage, the researcher identifies exciting phenomena to be researched. The researcher discusses several topics relevant to the education world today. Researchers formulate problems, objectives, and benefits of research.

2. Step 2
   At this stage, the researcher screened several studies that were relevant to the topic to be researched. Researchers select several articles to research based on various criteria such as journal reputation, year of publication, and, of course, the suitability of the topic to the research to be conducted. The articles are then recorded, sorted, and selected. 25 and 20 articles were determined to meet the criteria.

3. Step 3
   Researchers carry out article reviews by reading, examining, and analyzing all the articles that have been selected. This activity is carried out to find out and understand the overall content of the selected articles.

4. Step 4
   Based on the results of a thorough article review, some of the data needed to be reviewed is then taken. Data can be in the form of learning outcomes, characteristics, and improvements in learning outcomes.

5. Step 5
   The data is then collected and analyzed. Here, you can compare the results of various studies conducted. Data obtained from several articles were then compared with theories contained in the literature.

6. Step 6
   Conclusions are obtained based on the results of the analysis. Conclusions can be in the form of how to apply brain-based learning and the results that are likely to be accepted if you apply brain-based learning.

RESULTS AND DISCUSSION
Results
Twenty articles have been collected from a range of publications from 2016 to 2022, where the topic taken is the implementation of the BBL method to students ranging from middle school to college. Table 1 shows the articles that are used as references for review.

Table 1. Research results in the article.

Author(s)	Research result

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Prayogi & Widodo	The quality of learning using the BBL model using a scientific approach to the critical thinking abilities of class X students is included in the excellent category.
Lusiana & Andari	This indicates how the BBL method can improve students' higher-order thinking ability in logic and set courses.
Wardani et al.	The study's findings indicate that there are variations in students' higher-order thinking abilities between classrooms that use the BBL model and classes that use traditional approaches
Juniatri et al.	Whether used with students who have high or low critical thinking ability, the BBL model is appropriate for enhancing student learning outcomes because there is no interaction effect between critical thinking ability and student learning outcomes.
Zakaria & Purwoko	It is evident from several analyses of the study's results above that the BBL strategy is ideally suited for use in science education.
Permana & Kartika	When learning about temperature and heat, students' higher-order thinking abilities can be enhanced by utilizing the BBL technique.
Haryulinda et al.	The BBL-PBL model is declared to be valid, effective, and practical for gaining critical Thinking and Learning Outcomes
Saleh & Subramaniam	The results demonstrated that, compared to the traditional teaching approach, the BBTM is noticeably more successful in raising students' achievement in Physics and decreasing the gender disparity in Physics among regular school students.
Safitri & Hamid	Students responded positively to the use of BBL steps supported by mind-mapping
Zaqiah et al.	BBL learning can significantly improve elementary students' critical thinking ability in learning science.
Herliandry et al.	Applying the BBL model shows a good response and can improve students' critical thinking ability
Khoeriyah et al.	When studying Newton's law, the BBL model influences pupils' capacity for creative thought. Compared to the control group, the experimental group's capacity for innovative thought has increased.
Solomon et al.	Critical Thinking can improve students' grades and learning outcomes in an upper-level engineering course.
Diani & Fujiani	Using the BBL in terms of the average score on critical thinking tests, students' use of BBL impacts their ability to think more critically about static fluids.
Lestari et al.	Shows that the critical thinking ability of students in class XI MIA SHS Karya Pembangunan 2 Bandung experienced a significant gain after the application of the BBL model
Novalianti et al.	Students' critical thinking abilities are influenced by the BBL model's application and brain gym, where learning motivation affects students' essential thinking ability
Widyantari et al.	There is an influence of the BBL model on the critical thinking abilities of high school students in physics
Kusumawati	The BBL model physics learning tools that have been improved are suitable for training students' critical thinking abilities.
Achor & Gbadamosi	Higher academic success and retention are achieved by students

Author(s)	Research result
	using the BBL model technique compared to traditional learning methods.
Nwoye et al.	The crucial understanding that educational attainment and the learning process have been positively impacted by the BBL model and its methodologies

Discussion

In general, journal articles are in the form of open-access journals and restricted journals. Open-access journals are obtained from journal websites that the public can access via search engines for free. Restricted journals are not freely accessible to the public or in the sense that only those with access permission can read or download them. Obtaining access permission to restricted journals usually requires a particular or paid member. Meanwhile, the articles and journals used as references for review are open-access journals. Articles and journals were obtained from searches via Google Scholar with the keywords Brain-Based Learning, critical thinking ability, and their application to learning mathematics and natural sciences.

The articles used for review are limited to research in the natural sciences, which in this case includes mathematics, physics, chemistry, and biology. Through the ability to think, a person will be able to face and examine all the problems they face. Therefore, critical thinking abilities are essential (Sundari & Sarkity, 2021). The articles used are not only subject to students but also to students at the university level. Articles used as references are limited to 2016 to 2022 to maintain the novelty of the knowledge used.

The method used is a systematic review, which is research used to answer research topic questions in applying the BBL method to gain students' Critical Thinking. The results of the research data regarding literature studies were reviewed. The data obtained was then analyzed and summarized based on the subject matter related to problem-based learning, which was applied to train students' critical thinking ability (Ahdhianto et al., 2020; Liu & Pásztor, 2022; Nadeak & Naibaho, 2020; Razak et al., 2022; Yohannes et al., 2021). In conducting a literature review study, the discussion is carried out with the sub-topics of brain-based learning and critical thinking. From there, conclusions can be drawn about the influence of the two.

Application of Brain-Based Learning
The BBL model of education considers how the brain functions during the assimilation, processing, and interpretation of learned material. The learning stages use the BBL model approach, according to Jensen (2011).

Table 1. Brain-based learning's learning stage.

No	Learning Stage
1	Pre-Exposure
2	Preparation
3	Initiation and acquisition
4	Elaboration
5	Incubation and memory input
6	Verification and checking confidence
7	Celebration and Integration

The pre-exposure phase aims to aid in the brain's improved conceptual mapping. Preparing teachers fosters enjoyment and inquiry. The phase of start and acquisition comes next. This is the phase of connection formation, or when neurons exchange messages. The stage of neuronal communication, or elaboration, is when connections are made. The elaboration phase allows pupils' minds to categorize, investigate, evaluate, and expand on what they have learned. Memory entrance and incubation stages highlight the significance of repetition and relaxation times. During the verification phase, the instructor assesses the students' comprehension of their covered content. It is also necessary for students to determine their level of understanding. In the meantime, the last stage—celebration and integration—implores all the critical concepts of a love of learning (Farida, 2021)

Additionally, the BBL approach can help develop a variety of intelligences, including kinesthetic, logical, musical, intrapersonal, interpersonal, naturalist, verbal, and visual. Summary of Table 2 of scientific studies revealed that the use of the BBL model had an impact on students' learning activities, especially in science subjects at secondary school and tertiary level, carried out by Nwoye et al. (2022) and Solomon et al. (2022). The BBL model approach is very suitable and preferred by students to be applied in science learning compared to conventional learning (Achor & Gbadamosi, 2020; Saleh & Subramaniam, 2019; Zaqiah et al., 2022). The BBL method helps boost kids' interest in studying heat and temperature (Permana & Kartika, 2021).

Juniatri and Widyantari state that the BBL model has a considerable impact on physics learning results, while critical thinking abilities do not have a substantial interaction effect on physics learning outcomes (Juniatri et al., 2022; Widyantari et al., 2020). This aligns with Lusiana & Andari's (2020), which measures students' high-level thinking ability where the mean pre-test value is 57.65, the mean post-test value is 70.41, and the mean N-Gain value is 0, 32. The BBL model can improve students' thinking abilities in logic and set subjects. Other research also states that the BBL model using audiovisual media significantly differs from other conventional methods, where using the BBL model can improve students' high-order thinking ability (Wardani et al., 2022).

The BBL model can also be combined with several learning models, like Haryulinda et al. (2020). The effectiveness of the BBL-PBL model in obtaining cognitive learning outcomes with a score of 0.81 is categorized as high—-psychomotor learning results with a score of 82 in the excellent category. A critical thinking ability score of 85 is considered Very Good. In implementing the BBL model, the teacher is no longer the only source of learning for students (Akman et al., 2020; Amjad et al., 2023; Sugiarti et al., 2021; Yatim et al., 2022; Zuhriyah & Agustina, 2020). Still, through a conducive learning atmosphere, students can capture information from various sources such as textbooks, the internet, or teacher explanations.

Students' Critical Thinking Ability
In Indonesia, critical thinking abilities have often been promoted since the implementation of the 2013 curriculum and are still being announced until now, when the Merdeka curriculum has been implemented. One of the goals of 21st-century education that is being promoted is developing students' thinking ability, one of which is critical thinking ability (Pristianti & Prahani, 2022). Essential thinking ability includes using reason, thoughts, ideas, and creativity to work, develop, make decisions, and produce value (Pratami et al., 2022; Susilawati et al., 2020).

To form students' critical thinking ability, efforts are being made to develop interactive classes where students are actively involved in learning. According to (Facione, 2018) in Table 3, indicators of essential thinking skills.

Table 2. Indicators of critical thinking skills.

No	Indicators
1	Interpretation
2	Analysis
3	Evaluation
4	Inference
5	Explanation
6	Self-regulation

Research conducted by Zakaria and Purwoko (2021) states that critical thinking abilities must be acquired through education, specifically through developing future-ready living abilities. Students are declared to have the ability to think critically on five indicators, namely: 1) making decisions on problem-solving steps, 2) analyzing, 3) making inferences, 4) evaluating, and 5) making conclusions (Jatmiko et al., 2021; Neswary & Prahani, 2022; Rizki et al., 2023; Rohmah & Prahani, 2021; Saphira & Prahani, 2022). Learning media can help measure the critical thinking ability of BBL model students. The learning media is adjusted to the material's and students' characteristics. One reference learning model is to use a mind map. Differences in students' critical thinking abilities when applying BBL model steps supported by mind mapping with expository methods occurred, and students responded positively to using BBL model steps supported by mind mapping (Safitri & Hamid, 2022). Another example is carried out the BBL model with the help of Brain Gym, which can improve students' critical thinking ability (Novalianti et al., 2021).

Physics learning is carried out to determine whether there is an improvement in critical thinking abilities. The N-gain value of the average value of students' necessary thinking abilities is 0.46 in the medium category, with the BBL model, according to Wulandari, able to increase students' critical Thinking by 0.72 or in the Normalized gain categorization (Widyantari et al., 2020) according to Hake it is in the high category (Hake, 1999) with an N-Gain value of 0.62 with a medium interpretation shows that students' critical thinking ability become better after implementing learning with the BBL model. This situation is caused by the BBL model and essential thinking ability, which have a significant relationship with empowering students' brain potential. Meanwhile, other research states that the proportion of students' critical thinking abilities taught using the BBL model using a scientific approach is more than that of students' necessary thinking abilities taught using the direct learning model (Prayogi et al., 2017). High school or university students can consider using the BBL model to answer research objectives and gain students' critical thinking skills, especially in mathematics and science material. Based on the article review carried out, the BBL model can be applied to obtain critical thinking skills in mathematics and science material (Handayani et al., 2020; Haryulinda et al., 2020; Thurrodliyah et al., 2020; Zaqiah et al., 2022; Zulfatur, 2021). This is supported by the many theories and learning outcomes that support improving students' critical thinking skills in articles published in 2016-2022.

CONCLUSION

Fundamental Finding: According to a study using the review article approach, the BBL model can teach students to think critically. High-level cognitive abilities include critical thinking. Students must be able to maximize their brain's performance in order to practice this talent. This is possible with the help of the BBL model, which maximizes brain capacity to guide pupils towards optimal learning. **Implication:** The literature reviewed shows that the BBL model can be used as an option that teachers are considering to provide learning with the aim of training students' critical thinking skills. The BBL model can be given to students from middle school to college. **Limitation:** This research is limited to the results analyzed from 20 journal articles published in 2016-2022. **Future Research:** Furthermore, research can be developed to apply the BBL model directly to students at various levels.

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