DEVELOPMENT OF BRAIN-BASED LEARNING MODEL BASED ON PROBLEM-BASED LEARNING (BBL-PBL) TO IMPROVE CRITICAL THINKING AND LEARNING OUTCOMES

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Abstract

The 21st-century learning demands students' that have critical thinking skills. The learning model of Brain-Based Learning (BBL), combined with the approach of Problem-Based Learning (PBL), is an alternative model that adjusts the critical thinking skils. The objective of this research was to generate a valid, practical, and effective BBL-PBL learning model. This research was research and development using the ADDIE model, consisting of analysis, design, develop, implement, and evaluate. The study was implemented on the tenth-grade students of Rambipuji Senior High School, Jember, Indonesia, in the academic year of 2019/2020. The data collection techniques used were validation of products and test methods, interviews with the teachers, the questionnaire responses of teachers and students, and class observations. The results of the validity of the product were 91.4% as very valid category. The results of the cognitive model's effectivenest were of 0.81 as high category, the psychomotor aspects were 82 as fair category, and the critical thinking skills were of 85 as excellent category. The practicality results were obtained from the questionnaire responses of the teachers and the students, respectively by 91.2% and 86% which are both excellent categories.

Keywords*: Biology Learning, Brain-Based Learning, Problem-Based Learning, Critical Thinking, Learning Outcomes*

1. INTRODUCTION

The 21st -century learning requires every student to acquire skills in the face of globalization (Lin et al., 2018). Therefore, the 21st -century learning refer to 4C, i) critical thinking and problem solving, ii) communication, iii) collaboration, iv) creativity and innovation (Chai & Kong, 2017). The learning follows the 21st century biological learning, which is interdisciplinary, system-oriented, quantitative skills, problem-solving initiatives, and integrative (Wibowo & Sadikin, 2019).

However, based on the results of questionnaires through a google form of MGMP (teachers forum) of Biology of Senior High School in Jember, the learning outcomes and the level of critical thinking were still found low. It was because of a boring biology learning, the low enthusiasm of the students, and the decrease of their focus; thus the students had difficulties.

The difficulties in learning biology found at the secondary school were caused by ineffective learning models (Buah & Akuffo, 2017), and based on the results of the google form, the method that was often used by the teachers, namely lecture method of 72.2%. In the constructivist view, the teachers should not attempt to give out information into students' mind. Instead, the students should be encouraged to explore their world, discover knowledge, reflect, and think critically with careful monitoring and meaningful guidance of the teachers (Santrock, 2011). As a result, students tend to be passive in the learning process (Ghalley & Rai, 2019) and have low critical thinking skills (Amin et al., 2019).

The students may have critical thinking skills if one of the alternative approaches that is Problem-Based Learning (PBL) implemented. PBL is claimed to be able to develop critical thinking skills, because it can provide knowledge based on factual and applied, give a chance to assess the development of critical thinking skills, encourage students to inquire questions, and

direct students to study independently (Tan, 2004).

The learning process that is always emphasized critical thinking skills can produce a valuable and more fun learning experience (Boso et al., 2019). Therefore, the implementation of PBL in the learning process collaborates with a learning model that has a strategy of meaningful learning and fun as learning model Brain-Based Learning (BBL). The BBL model has a strategy to encourage teachers to conduct teaching by the conditions of the students and strives to create a pleasant emotional and challenging (Khalil et al., 2019). BBL learning model has a syntax which includes: (1) pre-preparation, (2) preparation, (3) initiation and acquisitions**,** (4) elaboration, (5) incubation and insertion memory, (6) verification and checking the credibility, and (7) celebration and integration (Jensen, 2008). PBL can be applied in BBL syntax, so it can produce a new syntax based on the criteria of a good learning model. Developing a learning model is necessary to support a pleasant learning process and increase student learning outcomes and improve critical thinking skills.

Critical thinking skills are much needed at this time so that students will not believe all information immediately; hence, they will always check the veracity of the information first, and get influenced easily (Ennis, 2011). Therefore, Brain-Based Learning model based on Problem-Based Learning, which is abbreviated as (BBL-PBL) can be implemented in schools. Therefore, the purpose of this research resulted in the development of brain-based learning model based on problem-based learning (BBL-PBL) for biology learning in senior high school.

2. RESEARCH METHOD

The Research Type

The type of research used in this study was research and development using the ADDIE model (analysis, design, develop, implement, and evaluate). The analysis phase involved identifying problems through a google form aimed at students and teachers, analyzing core competencies and basic competencies that result in indicators and learning objectives, analyzing the needs of students and teachers, and analyzing tasks. The design stage was formulating the learning objectives, developing the BBL-PBL model, determining the media, considering the supporting sources, and developing the learning tools. The develop stage conducted trials on a small scale. The implement stage was carrying out at the class scale. The evaluate stage collected feedback in the form of students' learning outcomes, and teachers' and students' questionnaire responses.

The Research Context and Participants

This study was conducted in Rambipuji Senior High School, Jember, Indonesia. The participants of this research were the tenth-grade MIPA-1' students in the first semester of 2019/2020 academic year, precisely in October until November 2019.

Data Collection Method

The data collection was obtained from the product validation by experts, the needs questionnaire of students, the needs questionnaire of teachers, pre-test and post-test scores, psychomotor scores, critical thinking skills scores, interview results with the biology teacher, observations, and documentation.

Data Analysis Technique

The data analysis technique consists of product validation, effectiveness model, and practicality analyses.

a. The Analysis of Product Learning Model Validation

The product validation of the BBL-PBL learning model consists of the validation of syllabus lesson plans pre-test and post-test, and the critical thinking skills by experts (lecturers) and the user (teacher). The validation of the product is in the form of quantitative and qualitative data, the data validation results will be analyzed using the following formula.

$$\text{Validation} = \frac{\Sigma\text{Obtained Score}}{\Sigma\text{Maximum Score}} \times 100 \text{.....(1)}$$

Table 1. The Validation Criteria of the BBL-PBL Model

Scores	Validity Categories	Information
84 ≤ x ≤ 100	very valid	Very ready to be used in the teaching and learning process.
68 ≤ x <84	Valid	It can be used however, by adding the lacking components. The addition is not too big and basic.
52 ≤ x <68	Valid Enough	It can be used with the condition of fixing the inappropriate components
36 ≤ x <52	Less Valid	The revisions are done by carefully reviewing and finding the weaknesses for improvement
20 ≤ x <36	Invalid	Revising almost all components

Handayani et al. (2018)

b. The Analysis of the Effectiveness Learning Model

The effectiveness of the BBL-PBL learning model was derived from the pre-test and post-test scores calculated by N-gain analysis (Sriyansyah & Azhari, 2017), the psychomotor scores calculated by the psychomotor assessment formula and the results of students' critical thinking skills formula presented as follows.

$$\text{N-Gain} = \frac{posttest - pretest}{100 - pretest} \quad \text{..... (2)}$$

Hake in Sriyansyah & Azhari (2017)

Table 2. The Criteria of N-gain Level

Scores	Criteria
normalized gain ≥ 0.70	High
≤ 0.30 normalized gain <0.70	Moderate
normalized gain <0.30	Low

Hake in Nissen et al. (2018)

The measurement of psychomotor learning outcomes is by evaluating the performance of discussions during the learning process, and observations conducted in the schoolyard. The psychomotor evaluation formula is as follows.

$$\text{Psychomotor} = \frac{\Sigma\text{Obtained Score}}{\Sigma\text{Maximum Score}} \times 100 \text{.....(3)}$$

Table 3. The Psychomotor Criteria

The Achievement of Scores (scores)	The Criteria
84 ≤ x ≤ 100	Excellent
68 ≤ x <84	Very good
52 ≤ x <68	Good
36 ≤ x <52	Fair
20 ≤ x <36	Poor

The critical thinking skills score (Cs) are analyzed by using the analysis techniques that are converted using a Likert scale, namely:

$$\text{Cs} = \frac{\Sigma\text{Obtained Score}}{\Sigma\text{Maximum Score}} \times 100 \text{.....(4)}$$

Table 4. The Criteria of the Critical Thinking Skills

The Scores	The Critical Thinking Categories
$83.35 \leq x \leq 100$	Excellent
$66.68 \leq x \leq 83.35$	Very good
$50.01 \leq x \leq 66.68$	Good
$33.34 \leq x \leq 50.01$	Fair
$16.67 \leq x \leq 33.34$	Poor
$0 \leq x \leq 16.67$	Very Poor

c. The analysis of the Practicality Learning Model

The practicality results of the BBL-PBL learning model were obtained from the teacher's response questionnaire and student response questionnaire given after the implementation of the learning model development process. The questionnaire results can be measured by the following criteria.

$$\text{Respons} = \frac{\Sigma\text{Obtained Score}}{\Sigma\text{Maximum Score}} \times 100 \text{.....(5)}$$

(Mertha *et al.*, 2019)

Table 5. The Practicality Criteria of the BBL-PBL Model

The Validity Level	The Validity Criteria
$84 \leq x \leq 100$	Excellent
$68 \leq x < 84$	Very good
$52 \leq x < 68$	Good
$36 \leq x < 52$	Fair
$20 \leq x < 36$	Poor

(Mertha *et al.*, 2019)

3. RESULTS AND DISCUSSION

Results of BBL-PBL Model

The process of developing the BBL-PBL model was carried out at the tenth-grade Science-1 of Rambipuji Senior High School using the ADDIE development model (analysis, design, develop, implement, and evaluate) the results are described as follows.

a. Analysis

The analysis stage results of the students' problems can be seen in Table 6 as follows.

Table 6. The Results of Analysis of the Students' Problems

The Analyzed Aspects	The Respondents' Answers	N	Total	(%)
What do you think of the learning process on biological materials?	Fun	132	29	21.9
	Boring		103	78.1
How is the learning process of biology that you get?	The lecture method	132	94	71.2
	The other method		38	28.8
Does the teacher during biology learning activities involve audio (video, music, etc.)?	Yes	132	59	44.7
	No		73	55.3
Does the teacher during biology learning activities, apply visual	Yes	132	52	39.3
	No		67	60.7

The Analyzed Aspects	The Respondents' Answers	N	Total	(%)
learning styles, such as presenting pictures, torso, etc.?				
Does the teacher during biology learning activities apply kinesthetic learning styles such as practicums, observations, etc.?	Yes No	132	30 102	10.0 90.0

Furthermore, the Basic Competencies 3.2 and 4.2 concerning biodiversity was analyzed, since these materials allowed observations in the schoolyard and caused the students to not get bored in class so that the learning could be fun.

The model was developed; hence, the task analysis was carried out, the results were tasks that could enhance an active students' centered learning and improve critical thinking skills through the Students' Worksheet (LKS).

b. Design

The design stage consisted of formulating learning objectives that were following the basic competencies 3.2 and 4.2 with the ABCD format (audience, behaviour, condition, degree), designing the development of the BBL-PBL model, which could be seen in Table 7.

Table 7. The Syntax of BBL-PBL Model

The BBL Model	The Characteristics of PBL	BBL-PBL Model
Pre-learning Giving a review of a new learning to the brain before it explores.		**Pre-learning** Doing Brain Gym accompanied by video.
Preparation Encouragement creates curiosity or excitement, with the aim of preparing learners.	• The problem is the starting point of learning.	**Preparation** Submitting the apperception, motivating in the form of HOTS questions related to the materials, delivering the learning objectives, and giving HOTS questions.
Initiation and Acquisition Giving knowledge by increasing the contents related to the lesson so that the learners get real experience through group projects, field studies, interviews, and experiments.	• The issues raised are usually real-world problems, require a variety of perspectives with interdisciplinary use, and challenge the students' competencies.	**Initiation and Acquisitions** Dividing groups heterogeneously. Providing material and videos related to real problems.
Elaboration The treatment requires thinking on learning by making the learning meaningful.	• Self-learning and collaborative learning systems. • The development of inquiry and problem-	**Elaboration** Group discussion and presentation of the results of the problem-based work on problems related to the materials.

The BBL Model	The Characteristics of PBL	BBL-PBL Model
	solving skills through cognitive exercises, and questions and answer	
Incubation and Insertion Memory Emphasizing the importance of time without activity (downtime) and time to review the learners' knowledge, because the brain learns most effectively all the time, not all at once.	• The end of the PBL learning process includes the synthesis and integration of learning. • PBL also ends with an evaluation that includes a review of learning experiences and learning processes.	**Incubation and Insertion Memory** Relaxing with instrumental music playback when it is time writing the conclusions. Straightening the concept and adding less material. Asking HOTS questions about issues related to the materials.
Verification and Checking the credibility Giving quizzes and writing the learning material points to confirm understanding.		**Verification and Checking the Credibility** Recording points matter and conclusions. Giving HOTS questions relating to the material.
Celebration and Integration Engaging enjoyable emotions. The goal is to instill a liking towards learning.		**Celebration and Integration** Awarding and checking tasks.

Jensen (2008)

c. Develop

The development stage is the process of realizing a blueprint that has been compiled into reality which is realized in a small-scale trial with 9 students who have different abilities that produce revisions to the BBL-PBL model starting from syntax, reaction principle, social system, accompaniment impact, impact instructional, and produce cognitive and psychomotor learning outcomes. The result of learning and critical thinking skills test on Small Scale on BBL-PBL models can be seen in Table 8.

Table 8. The Results of Learning and Critical Thinking Skills Test on Small Scale (N = 9)

Aspects			Category
Cognitive	**Pre-test Mean ± SD**	38.2 ± 15.53	
	Post-test Mean ± SD	80 ± 2	
	N-gain	0.68	Moderate
Psychomotor	**The mean value ± SD**	73, 22 ± 3.42	Good
Critical Thinking Skills	**The mean value ± SD**	71 ± 2.84	Good

d. Implement

Implementation stage embodies the BBL-PBL model applications at scale class with 35 students who produce the results of learning and critical thinking skills.

Table 9. The Results of Learning and Critical Thinking Skills Test on Class Scale (N = 35)

Aspects			Category
Cognitive	**Pre-test Mean ± SD**	51.30 ± 18.2	
	Post=test Mean ± SD	91 ± 6,14	
	N-gain	0.81	High
Psychomotor	**mean ± SD**	82 ± 3	Good
Critical Thinking Skills	**mean ± SD**	85 ± 5	Very good

e. Evaluate

The evaluation stage occurred at the development and implementation stage in the ADDIE model, which was in the form of the revision of those stages. Revisions were made relating to the validity, practicality, and effectiveness of the model implemented in the learning process. However, the evaluation stage's main point was to collect feedback from students that could be seen through the results of the learning and a questionnaire of the practicality of the model that produced students' and teachers' responses. The result of validity, teachers' and students' responses to BBL-PBL models can be seen in Table 10, 11, and 12.

Table 10. The Validity Result of BBL-PBL Model

Instruments	Validation Mean ± SD	Category
Handbook of learning model	91.4 ± 0.75	Very valid
Learning syllabus		
Lesson plan		
Pre-test and post-test questions		

Table 11. The Results of the Analysis of Teachers' Responses Questionnaire

Indicators	Mean ± SD	Category
The clarity of instructions in using lesson plan	91.2 ± 10.35	Very good
Competency achievement and goals		
Students' responses		
Difficulty level in the implementation		
Adequacy of time		

Table 12. The Results of the Analysis of Students' Responses Questionnaire

Indicators	Mean ± SD	Category
Interest in learning	86 ± 2.51	Very good
Usefulness in the following learning		
Interest in the following learning for the next chapter		

Discussion

Based on the results of the analysis stage of the overall problems, it was found that students had learning difficulties in the learning process. The problem of learning difficulties experienced by students can be caused by the less preciseness of the learning model used by the teacher; so that can be made the students bored with what the teacher said, the activeness of the students in

the learning process was less, students sometimes tend to play around in the classroom during the teaching and learning process, such as: chatting with classmates, going out of the classroom, being noisy and doing lots of other activities that can disturb the teaching and learning process and can affect the learning outcomes (Samad & Mangindara, 2019). As a result, the major problem that remained common in learning was about the students' low learning (Lukman et al., 2019). Therefore, the researcher's alternative solution was developing a Brain-Based Learning based on Problem-Based Learning (BBL-PBL)

BBL facilitates students with fun learning, no threatening, and can promote relaxation (Laksana et al., 2019). Besides, it is fun; it also follow the PBL-based problems. PBL includes a complex real-world problem, that is used to motivate students to identify and research concepts and principles to solve real- world problems. Students worked in small learning groups, brought together the collective skills, communicated, and integrated it (Duch, 2001).

The development of BBL-PBL model was done by combining the characteristics of PBL with the syntax model of BBL, which generated new syntax like arranged in the design stage. The development of this model was supported by the preparation of the learning device following the BBL-PBL models.

The supporting learning device of BBL-PBL models was used to be tested on a small scale with 9 students with different academic abilities and different genders. Learning on a small scale is active and meaningful learning since it is supported by the appropriate learning device and learning media. Learning media greatly help students easily understand the learning material (Kristanto et al., 2019). Challenging learning can make students always feel free to learn (Saleh & Mazlan, 2019).

A small-scale trial produced a revised model of BBL-PBL from the syntax, the reaction principle, the social systems, the instructional impact, and the additional impact. The model that had been tested on a small scale was followed by the trials in a class-scale with 35 students who used the syntax that had been improved from small-scale trials.

The results of the class-scale trials determine the validity, effectiveness, and practicality of BBL-PBL models. Before applying BBL-PBL model in this study, this model was validated by the chosen validators. Validators saw the elements that must exist in a learning model developed, such as syntagmatic, social system, the principle of reaction, supporting systems, instructional impact, and additional impact by giving a rating based on the Likert scale. Based on the validation results, it can be seen that the BBL-PBL model was categorized as very good, which means that it is valid so that BBL-PBL model can be arranged in a guide book of BBL-PBL models.

In addition to the validity of the BBL-PBL model, there was the effectiveness of BBL-PBL learning model, which can be seen from the measurement results of pre-test and post-test that used one or more classes known as "one group pre-test post-test design". This "one group pre-test post-test design" is a study that used one class that will be measured and will be given treatment and re-measurement after doing treatment (Susani et al., 2019). The calculation of pre-test and post-test was analyzed using N-gain. The N-gain analysis was an appropriate analysis to measure the results of pre-test and post-test from many students with different levels of knowledge (Nissen et al., 2018).

From the results, the effectiveness score of BBL-PBL model can be seen. The improvement of learning outcomes and critical thinking skills were caused by the growing number of learning activities done by the students, such as Brain Gym activities, analyzing the real problem in the neighborhood, doing discussion, and observating through pictures and direct observation schoolyard relating to the materials. The increased activity makes students' synaptic nerve becomes more connected and makes students' thinking is more complex (Handayani & Corebima, 2017).

More complex thought can make a brain-healthy, which is very useful to

increase memory, concentration, focus, and so on. Hence, a person's success is determined by his brain's quality, both right brain and left brain. Brain Gym is an alternative solution to help the children overcome a lack of concentration; and stimulate the brain to receive information easily, which has a simple movement and not tiring and can be done anytime and anywhere (Komarudin et al., 2019). Brain Gym's impact is can improve various outcomes including attention, memory, and academic skills (Dennison & Dennison, 2005).

Besides, the activities that had been implemented in the learning process were maximized with their supporting media such as video and music. Music can be effective in the academic field to help the formation of learning patterns, cope with boredom and avoid disturbing external noise. Also, music actively influences the development of the mental and physiological brain. This activity helps the formation of the neural pathways associated with the brain and encourages the establishment of relationships between cells of the brain. It can improve a person's mental and physical growth (Roffiq et al., 2017).

The improvement of mental growth with music is suited to the student's learning style. Learning styles become an essential aspect in the success of students' learning since it deals with how students begin to concentrate, process, internalize and remember the new academic information (Dunn & Griggs, 2000).

The effectiveness of BBL-PBL model, besides seen from the improvement of learning outcome, was also seen from the improvement of critical thinking skills. The results of students' critical thinking skills improved every meeting. The critical thinking skills was due to the learning process, which was always based problems, ranging from pre-learning activities with HOTS questions, core activities containing doing LKS based problems along with watching video-based problems, and doing discussion so that it was by the PBL approach. PBL learning activities that are problem-oriented stimulate high-level thinking skills to find solutions for the problems (Fitriani et al., 2020). PBL was used to enhance critical thinking skills, so that problem-based learning system was considered as the most appropriate teaching approach (Winarno et al., 2018).

The practicality of the BBL-PBL learning model was obtained through a practical questionnaire of teachers' responses and practicality questionnaires from students' responses. The results of the data obtained from the practicality questionnaires of teachers' responses showed that the BBL-PBL model can be used very well, thus the BBL-PBL model was practical and easy to use by the teachers.

The results of the data obtained from the practicality questionnaires of students' responses showed that the excellent category deals with learning interest, which means that learning interest is very significant. Interest has been rated as a major component of academic achievement for more than a century. Interest is also considered by many cognitive psychologists to become an important component of motivation to learn (Rowland et el., 2019). The motivation for students to learn science increased due to the BBL learning model that maximizes the brain (Sani et al., 2018).

The learning model is a practical if a model already contains statements from experts and users (teachers) that the learning model can already be developed and can produce a fact that shows outcome in the form of positive response from teachers and students (Jalil et al., 2016). The use of learning as described above is following the demands of the 21st century learning to maximize the brain in thinking.

4. CONCLUSION

BBL-PBL learning model that had been developed was 91.4 as a very valid category. The effectiveness of the BBL-PBL model acquired cognitive learning results with a score of 0.81 categorized as high. Psychomotor learning outcomes with a score of 82 categorized as good. A critical thinking skill with a score of 85 was considered very good. The practicality of BBL-PBL models from the result of teachers' response of 91.2% was categorized as a very good category means that it was very practical. Students' response by 86% included in the

excellent category, means that it was very practical. Based on these results, the BBL-PBL model declared to be valid, effective, and practical to implement.

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