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iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 18 No. 9 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijim.v18i09.48097

PAPER

Development of PBL-Based GLOWASEA (Global Warming on the Sea) Educational Media to Train Critical Thinking Skills on the Topic of Global Warming

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ABSTRACT

The low critical thinking skills of Indonesian students in the 21st century indicate the necessity of training these skills to prepare for a future replete with challenges. Teachers need to innovate learning materials that foster critical thinking skills. This study aims to develop a PBL-based GLOWASEA Edukit media product that is valid, effective, and practical for enhancing students' critical thinking skills. This developmental research was conducted following the ADDIE model, which comprises five stages: analysis, design, development, implementation, and evaluation. Qualitative data were obtained through comments and suggestions for improvement in questionnaires and interviews. Quantitative data were obtained from the scores on the validation test, practicality test, questions' validity and reliability test, and pretest and post-test score data. Data were analyzed using percentage analysis and qualitative description. Successively, the results of media and material validation and practicality were 82.61%, 91.17%, and 90.62%. The effectiveness of Edukit media is calculated using the N-Gain formula, resulting in an average score of 0.33, which meets moderate criteria. It can be concluded that the GLOWASEA Edukit media produced is valid, effective, and practical for training students' critical thinking skills.

KEYWORDS

learning media, Edukit, problem-based learning (PBL), critical thinking, global warming

1 INTRODUCTION

1.1 Research gap and literature review

Education plays a significant role in the progress and growth of a country. Advances in science and technology, globalization, and the internationalization of education are considered challenges that a country must face. One of the key

Mutma'innah, F., Hamimi, E. (2024). Development of PBL-Based GLOWASEA (Global Warming on the Sea) Educational Media to Train Critical Thinking Skills on the Topic of Global Warming. *International Journal of Interactive Mobile Technologies (iJIM)*, 18(9), pp. 117–140. https://doi.org/10.3991/ijim.v18i09.48097

Article submitted 2024-01-27. Revision uploaded 2024-02-28. Final acceptance 2024-03-06.

focuses of educational challenges is 21st-century skills among students [1]. Cognitive skills are a key focus of the 21st-century skills-organizing approach. Cognitive skills include problem-solving, critical thinking, and systems thinking [2]. This is a new challenge for the government in its endeavors to enhance the quality of education. According to [3], critical thinking is considered one of the higher-order thinking skills that should be at the core of learning development. It equips individuals with life skills, creativity, and innovation, enabling them to effectively solve complex problems in the 21st century.

Critical thinking skills involve analyzing and evaluating information and arguments, as well as fostering a strong curiosity to solve problems [4–6]. Facione and Gittens [7] state that critical thinking consists of several primary skills: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Ability in science is closely related to the capacity to systematically investigate and comprehend nature and its phenomena. This involves understanding concepts, theories, and formulas that must be well studied. Therefore, students are expected to be able to think critically when constructing their knowledge independently and to play an active role in the learning process [8].

The critical thinking skills of Indonesian students are reported to be low. This is evidenced by the research results by [9], which concluded that the average achievement of students in the correct answer categories needed to be higher in questions related to critical thinking ability. Research by [10] also supports this statement with its analysis, which indicates that students' inference skills in critical thinking score 30% with low criteria, while explanation skills earn 20% with very low criteria. Furthermore, the analysis of critical thinking skills conducted by [11] indicates that most students critical thinking skills still need improvement. Based on data from PISA in 2018, Indonesia is ranked 8th from the bottom out of the 68 countries participating in the computer-based assessment. More than 55% of the students who participated indicated low achievement in science [12]. Other data based on TIMSS in 2011 and 2015 indicated that Indonesia was ranked 6th and 4th from the bottom in science [13], [14].

Field data or needs assessment data obtained from interviews with science teachers, as well as questionnaires distributed to students in one of the schools in Batu City, indicate that science lessons conducted by teachers have developed critical thinking skills but have not been optimal and have not influenced students' habits. This can happen due to the limited educational resources and the insufficient science laboratory facilities in schools. When considering students' critical thinking skills, it is essential that more than 50% of their time be dedicated to practicing and honing these skills. Accordingly, over 60% of the students who filled out the questionnaire agreed that it was difficult to respond to the problem in depth. The teacher also mentioned the challenge of training students' critical thinking skills due to variations in the abilities possessed by each student. The lack of student engagement in science learning may be the cause of this issue. In addition, an analysis of the learning resources used by teachers and students revealed that the books utilized were compiled by the Ministry of Education and Culture of the Republic of Indonesia. The discussion of global warming material is limited and combined with the human influence on ecosystems sub-chapter. Therefore, we need a solution that can overcome this issue, such as utilizing straightforward learning materials to enhance engagement and develop students' critical thinking abilities during the learning process.

The low critical thinking skills of students are caused by several factors, including the lack of real-life experiences that students encounter through integrated curriculum and learning approaches [8]. Even through experience, students can find and construct their knowledge independently, so they do not only remember or memorize

the facts and concepts taught [15]. The low skills are also caused by the implementation of teacher-centered learning approaches that rely heavily on lectures, resulting in less student engagement in the teaching and learning process [11], [16–18]. In addition, problem-solving activities can help train students' critical thinking skills. By solving problems, students not only memorize or recall their knowledge but also relate it to their experiences [19]. Therefore, we need something that can engage students in active learning, provide real-life experiences, and enhance their critical thinking skills. According to [20], using learning media will increase student engagement in teaching and learning activities.

Learning media are all physical or technical elements that facilitate teaching and learning activities, enabling teachers to convey material more effectively and achieve predetermined learning objectives [21]. In learning activities, teachers use educational materials to communicate with students. The learning process that utilizes educational media will offer meaningful experiences for students [22]. Using suitable learning materials can offer convenience for students in organizing their understanding and thoughts about abstract concepts [23]. For this reason, using media in science learning is essential to facilitating students and teachers. However, based on previous research, media use still needs to be improved or utilized more in school learning [24].

Experimental tools and materials are essential learning resources that can be utilized in the educational process. Experimental activities require tools, materials, and student worksheets. This is an opportunity for teachers to explore students' critical thinking skills [25]. The research by [26] also concluded that experimental activities could enhance students' critical thinking skills. But some schools were unable to conduct experiments due to limited facilities and funds [27], [28]. A learning or educational kit (EduKit) is a teaching tool assembled and organized as a unit box for learning, designed as a set of experimental tools for developing process skills in science studies [29]. Teaching aids and experimental tools made in kit form will be simpler to maintain. In addition, the tools and materials are contained in one container, so they are not scattered, and there is no need to look for each part when they are to be used [30].

Using existing learning materials does not develop students' problem-solving skills, as in the case of workbooks that only provide text and lack appeal to students' motivation to learn [31]. Therefore, it is necessary to develop learning materials to assist students in practicing problem-solving skills associated with critical thinking. Problem-based learning (PBL) is a hands-on approach with the teacher acting as a facilitator [32]. It focuses on real-world problems that students may encounter and requires them to solve these problems using their existing knowledge and skills [33], while also encouraging them to explore various sources to acquire new information [34]. In its application, this model encourages the active involvement of students in the learning process and provides space for them to apply their knowledge [35]. Amin [36] states that PBL utilizes real-life scenarios to acquire knowledge and make decisions through problem-solving and critical thinking. Research by [37] shows that the average learning outcomes with the PBL learning model are higher than the direct instruction model on indicators of critical thinking skills. Therefore, learning with the PBL model can develop critical thinking skills.

In junior high school science education, one of the topics that relates to real-world issues is global warming. It discusses the meaning, causes, impacts, and efforts to combat global warming [38]. Global warming education materials encompass real-world scenarios and intricate processes, emphasizing comprehension over rote memorization [39]. Therefore, learning materials are necessary to help students comprehend concepts through experience and encourage information retrieval. In addition, global warming is an environmental issue that has been receiving

serious attention lately. Therefore, critical thinking skills are necessary to accomplish the learning objectives outlined in the learning outcomes [40].

Based on previous research, using science learning kits as learning tools can stimulate student engagement and enhance conceptual understanding and critical thinking skills [41–43]. Learning kits or educational kits have seen significant development. One example is a kit that focuses on climate change, covering topics such as rising oceans, wind patterns, and carbon dioxide emissions. However, education about global warming, which focuses on discussing the impact of global warming on the sea, is still limited to basic concepts and findings from research conducted by [29]. In addition, it was also found that several previous studies have developed alternative learning materials, such as worksheets, to enhance critical thinking skills, but these materials were not accompanied by learning kits. Therefore, the study will be conducted to explore existing ideas about Edukit with various modifications based on specific learning models that can be tested on students.

1.2 Research questions

RQ1: What is the validity of PBL-based GLOWASEA Edukit media in training students' critical thinking skills on the topic of global warming?
RQ2: How effective is the PBL-based GLOWASEA Edukit media in training students' critical thinking skills on the topic of global warming?
RQ3: What is the practicality level of the PBL-based GLOWASEA Edukit media in training students' critical thinking skills, as perceived by teachers and students?

2 RESEARCH METHODOLOGY

2.1 Research design

The conducted study is focused on research and development, a method used to produce specific products and test their effectiveness [44]. This study uses the ADDIE (analyze, design, develop, implement, and evaluate) research model [45]. The ADDIE model was chosen because of its practical development stages in creating learning tools, professional and dynamic practices, and supporting the learning process [46]. Another reason for choosing the ADDIE model is that it is suitable for developing instructional media and demonstrates precise and meticulous product production procedures. A diagram of ADDIE's research steps is presented in Figure 1.

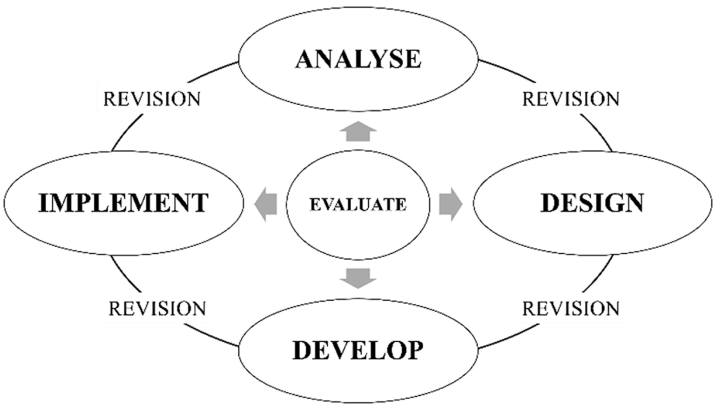

Fig. 1. ADDIE model diagram

Analyze. At this stage, activities are being carried out to assess the needs of one of the junior high schools in Batu City. This activity was conducted with one of the science teachers and students. For science teachers, the analysis was conducted through interviews following the established guidelines. During the analysis of students' needs, questionnaires were filled out. At this stage, an analysis of the curriculum and materials used is also conducted. In addition, content research is also conducted on educational issues, learning kits, or Edukits, and materials related to global warming through literature studies.

Design. A design is carried out regarding the contents of the learning kit, the manufacturing process of the kit, the necessary materials for its production, and the assessment and testing devices for the learning kit. The supportive devices in question include teaching modules and various assessment instruments. In this phase, an instrument was designed to assess students' critical thinking skills before and after using the developed product.

Development. The framework prepared in the previous step has been developed into a product ready for testing. The product is the GLOWASEA Edukit media, along with its manual book. In addition, there are teaching modules, worksheets, handouts, and assessment instruments. The developed assessment instrument is based on critical thinking indicators developed by Facione. At this stage, the products that have been developed are validated by material and media experts. After the product has been validated by experts, the next step is to assess the validity and reliability of the questions or instruments for evaluating critical thinking skills. After obtaining valid and reliable results, the critical thinking assessment instrument can be used to measure students' ability through pretests and post-tests to determine the initial conditions and the results of this developmental research.

Implement. Edukit and its tools were tested on research subjects during the implementation stage. At this stage, teachers and students evaluate the practicality of the Edukit that has been developed.

Evaluate. The evaluation stage is conducted at the end of each step. This is because the developed product needs improvement by revising at each stage.

The study subjects were a teacher and thirty-two students in the seventh grade at one of the junior high schools in Batu City. The research design used is a pre-experimental design with one group pretest post-test. The choice of this design is so that the experimental results can be accurately determined by comparing the results obtained with the initial state using pretest and post-test values [44].

2.2 Data collection and the instruments

Data collection techniques for training critical thinking skills involve validation, effectiveness, and practicality tests. The instruments used to collect data included validation questionnaires for material experts and media experts, practicality questionnaires for teachers and students, and test sheets to assess students' critical thinking abilities. The research instrument was prepared based on the adaptation of the assessment components by BSKAP and Permendikbud RI, and it was informed by various relevant literature [47–50]. The question sheet for critical thinking skills consists of six pretest questions and six post-test questions. The questions are in the form of essays and are arranged according to indicators of critical thinking skills by Facione, which include interpretation, analysis, evaluation, inference, explanation, and self-regulation [51]. Question pretest and post-test are compiled with the same indicators and at an equivalent cognitive level; what distinguishes between the two is the context or problem being discussed. In this study, the data obtained

were in the form of qualitative and quantitative data. Qualitative data is derived from comments and suggestions for improving media and material validation tests, as well as assessing the practicality for students and teachers. The quantitative data is derived from scores obtained through the validation of media and materials by expert validators, testing the validity and reliability of questions by eighth-grade students or those who have studied global warming material. The data also includes an assessment of students' critical thinking skills and feedback on practicality from both students and teachers. Media and material validity tests refer to the Likert and Guttman scales, which are used in practical questionnaires for teachers and students, employing a Likert scale. The Likert scale referred to is an interval scale, with the lowest score being 1 for strongly disagreeing and the highest score being 4 for strongly agreeing [52]. On the Guttman scale, there are two answer choices: "Yes" and "No," with scores of 1 and 0, respectively [44].

2.3 Data analysis

A validation test is one of the essential requirements that learning media must meet. The level of validity refers to how appropriate the developed material is in line with the relevant knowledge and skills and the extent to which the overall material is consistent and well connected [53]. The practicality test is a standard measurement of product practicality [54], conducted by gathering feedback from teachers and students [55]. The validation and practicality test data obtained are then calculated and analyzed with the average analysis technique using the formula in Equation 1.

$$P = \frac{\sum R}{n} \times 100\% \quad (1)$$

Information:
P = Validity or Practicality (%)
∑R = Score Obtained
n = Maximum Score
Source: Modified from [56]

The results of the percentage validity of the media and materials developed, as well as the practicality percentage results in this study, are detailed in Table 1.

Table 1. Validity and practicality criteria

Validity/Practicality (%)	Criteria
$80 < x \leq 100$	Very Valid/Very Practical
$60 < x \leq 80$	Valid/Practical
$40 < x \leq 60$	Enough
$20 < x \leq 40$	Less
$x \leq 20$	Invalid/Impractical

Source: [57], [58].

A validity test is a method used to evaluate the suitability or feasibility of each question in the questionnaire to measure a specific variable. Meanwhile, reliability reflects the stability and consistency of respondents in answering questions related to the dimensions of the variable being measured [59]. The data obtained were analyzed

using analytical techniques, specifically the Pearson Product-Moment Correlation to test empirical validity and the Cronbach's alpha formula for the reliability of the questions, through the IBM SPSS 25 Statistics software. The results of the validity of the questions used a significance level of 1%. If the value of $T_{Count} > T_{Table}$, then they are declared valid [60]. As for the reliability of the questions, the questions are considered reliable if the Cronbach's alpha value obtained is greater than 0.6 [59], [61].

The data obtained from pre- and post-tests will be analyzed to assess normality and differences using the t-test. Both tests were performed using IBM SPSS 25 statistics software. Due to the small sample size of 50, the Shapiro-Wilk test was used to assess the normality of the data. The error rate in decision-making is set at 5%, or 0.05. The decision-making criterion refers to the significance value. If the significance is higher than 0.05, then the research data is declared normally distributed [60]. Next, for the t-test, differences are being conducted. This is done to determine whether there is a significant difference in the average data between the pretest and post-test. The results of the t-test data were then analyzed. If the significance value is higher than 0.05, Ho is accepted, and Ha is rejected. If the significance value obtained is less than 0.05, Ha is accepted, and Ho is rejected [62]. The following is the hypothesis used for this study:

Ho: There is no significant difference in the value of students' critical thinking skills before and after using Edukit GLOWASEA.
Ha: There is a significant difference in the value of students' critical thinking skills before and after using Edukit GLOWASEA.

Pre- and post-tests will be conducted to assess the level of critical thinking skills. The results will be analyzed using N-gain tests to evaluate the effectiveness of learning with the newly developed GLOWASEA Edukit. The effectiveness test is used to calculate the degree of conformity between product results and the objectives to be achieved [63]. The formula for N-gain can be seen in Equation 2.

$$\text{N} - \text{Gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Ideal Score} - \text{Pretest Score}} \quad (2)$$

Source: [64]

The effectiveness criteria in this study are presented in Table 2.

Table 2. N-gain criteria

N-Gain Score	Criteria
$0.70 \leq g \leq 1.00$	High
$0.30 \leq g < 0.70$	Moderate
$0.00 < g < 0.30$	Low
$g = 0.00$	No Increase
$-1.00 \leq g < 0.00$	Decreased

Source: [65].

3 RESULTS AND DISCUSSION

The development research was based on the ADDIE research procedure, which consists of several stages. The first stage of this development research is analysis.

At this stage, a needs assessment has been implemented. An analysis of teachers' needs was conducted through interviews. The results of interviews with teachers indicated that students' critical thinking skills still needed improvement, and it was also deemed quite challenging to engage students in active learning. Furthermore, teachers also encounter challenges in conducting experimental activities due to insufficient science laboratory facilities in schools. This was also found in a study by [28], which states that experimental activities are rarely conducted due to inadequate science laboratory facilities and infrastructure. Learning activities are conducted using textbooks provided by the school and supplemented with Internet references when necessary. An analysis of students needs is conducted by completing questionnaires. The results obtained showed that 90.6% of students preferred learning science through experimental activities; 78.1% of students required kits as learning aids; 56.2% of students still perceived science as a challenging subject; and 52.5% still exhibited low critical thinking skills. In research conducted by [66], it was found that more than 50% of all research subjects still possessed low critical thinking skills.

The second stage of this study is the design stage. At this stage, the Edukit GLOWASEA and guidebook were designed. At this stage, teaching modules were also designed, including learning scenarios, worksheets, and handouts about global warming. The content of the handout was developed following the guidelines outlined in the student handbook by [67] and applicable discussions. Additionally, the instrument questions for the pre- and post-tests were also designed at this stage based on the critical thinking indicators by Facione. The compiled GLOWASEA Edukit consists of four experiments focusing on the impact of global warming on the oceans. The box design and experimental setup are depicted in Figure 2.

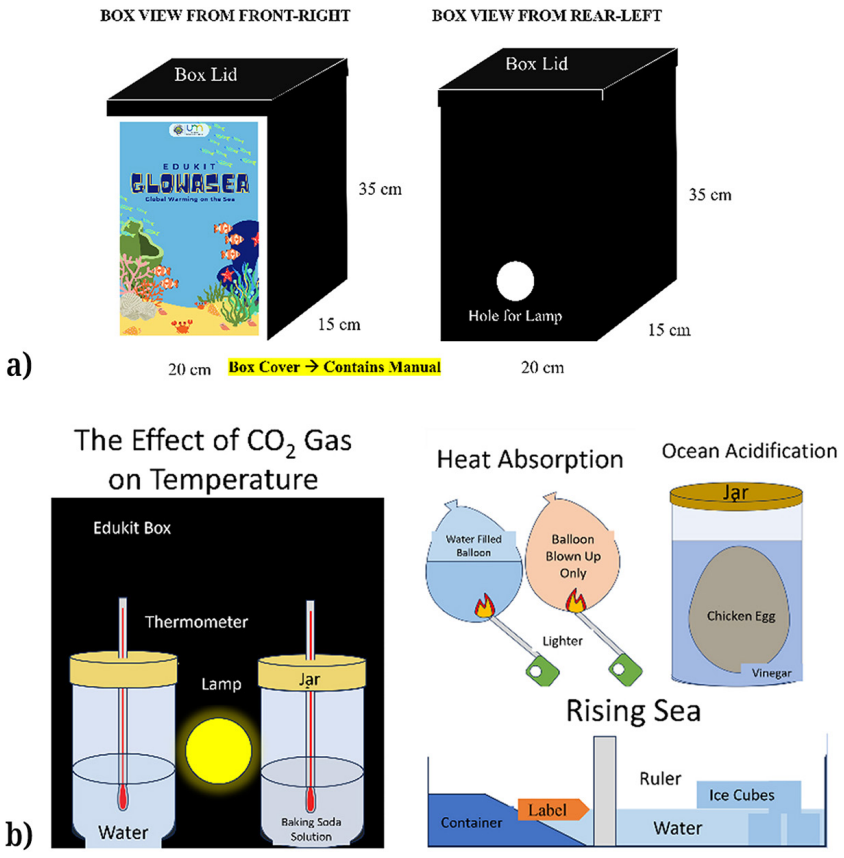

Fig. 2. GLOWASEA Edukit design; (a) GLOWASEA Edukit box; (b) GLOWASEA Edukit loaded experiments
Source: Personal documents.

The third stage of this study is the development stage. At this stage, development was carried out following the design that had been created in the previous stage. The first thing that was developed was the Edukit GLOWASEA. The Edukit box was made with acrylic material because it serves a dual function: as a container for the Edukit itself and as a tool for experiments. The use of acrylic material is intended so that the components inside can be visible [68]. The tools and materials provided in the box include a 250-ml jar, a 170-ml jar, a stirring rod, a bulb, a ruler, a container, an ice cube mold, an alcohol thermometer, a set of wires for the lamp, plasticine, rubber balloons, labels, vinegar solution, and baking soda. The tools and materials for each experiment in the Edukit box are packed in cardboard to ensure they are neatly arranged and safe from damage [69]. In addition to the experiment tools and materials mentioned, Edukit also includes several manuals that explain the GLOWASEA Edukit's description, operation, and the experiment steps. The manual book also includes a QR code that will display the experiment video and printable student worksheets. The QR code provided can be scanned using Google Lens or other QR code scanning tools or apps that support it. The Edukit manual is printed on art paper, commonly used for brochures or leaflets, in A4 size and consists of four pages [70]. The manual book is packaged in a large envelope that also serves as the cover of the Edukit box. The experiments included in the Edukit cover heat absorption by water, the impact of carbon dioxide gas on temperature, ocean acidification, and sea level rise. GLOWASEA Edukit and its components can be seen in Figure 3.

Fig. 3. GLOWASEA Edukit display includes: (a) Edukit box outside view; (b) Edukit box and components; (c) Packaging of Edukit components per experiment; (d) Manual book; (e) Scanned QR code for video experiment steps; (f) Scanned QR code for student worksheets

Source: Personal documents.

In addition to developing Edukit, this study also created teaching modules that include worksheets, handouts, and sets of questions for pretests, and post-tests, all

based on indicators of critical thinking skills. Worksheet products are equipped with various features based on PBL syntax aspects. The mapping of PBL syntax, critical thinking skills, and worksheet features is presented in Table 3.

Table 3. Mapping PBL syntax, critical thinking skill indicators, and worksheet features

PBL Syntax	Critical Thinking Skills Indicators	Worksheets Features
Student Orientation to the Problem	Interpretation (Decoding Significance)	Let's Observe!
	Interpretation (Categorization)	Let's Ask Questions!
Organizing Students	Analysis (Assessing Ideas)	Let's Discuss!
Guiding the Investigation	Interpretation (Categorization)	Let's Investigate!
	Inference (Looking for Evidence)	
	Inference (Thinking of Alternatives)	
	Inference (Drawing Conclusions)	
	Analysis (Detect Arguments)	Let's Write!
	Evaluation (Assessing Claims)	
Developing and Presenting Results	Explanation (Delivering Results)	Let's Be Creative!
	Self-Regulation (Self-Assessment)	
Analyze and Evaluate the Problem	Explanation (Presenting Arguments)	Let's Speak Up!
	Evaluation (Valuing Arguments)	
	Self-Regulation (Self-Assessment)	

For the handout, which is used as a learning resource compiled based on valid references about global warming. There are several subtopics in the discussion, including the definition of global warming, its causes, impacts, and efforts to mitigate global warming, along with a glossary of foreign terms for students. For the pretest and post-test questions, we followed the parameters of critical thinking skills proposed by Facione. The display of teaching modules along with worksheets and handouts is presented in Figure 4.

Fig. 4. GLOWASEA Edukit support device display; (a) Teaching module display; (b) Worksheet display; (c) Handout display

Source: Personal document.

At this stage, the GLOWASEA Edukit and its equipment were validated by media and material experts to assess their validity. The results of the media validation test are presented in Table 4.

Table 4. Validity of GLOWASEA Edukit media

No.	Validation Aspect	Score Gained (%)	Criteria
1.	Content Graphics	82.99	Very Valid
2.	Teaching Modules Graphics	86.00	Very Valid
3.	Usage	91.67	Very Valid
4.	Language	77.50	Valid
5.	Suitability with PBL	75.00	Valid
Average		**82.61**	**Very Valid**

Based on the media validation data presented in the table, the GLOWASEA Edukit and its equipment scored 77.50% with valid criteria in terms of linguistic aspect. Ease of use, compliance with Indonesian language rules, and reference writing are commendable. In principle, the language used in learning materials is related to selecting appropriate vocabulary, ensuring sentence effectiveness, and crafting coherent paragraphs. The linguistic aspect is an essential factor that needs to be examined because using excellent and appropriate language will make it easier for readers to understand information and instructions [71]. For compatibility with PBL, the GLOWASEA Edukit and its equipment scored 75.00% based on valid criteria. This is because the Edukit and its equipment fulfil the aspects of PBL well. The PBL model consists of five sequential/ learning stages: student orientation to problems, organizing students, guiding investigations, developing and presenting results, and problem analysis and evaluation [35]. The five stages have been outlined in the activities on worksheets. Overall, Edukit GLOWASEA and its equipment obtained a score of 82.61%, which can be considered highly valid. Therefore, the media expert validator stated that the GLOWASEA Edukit and its equipment can be used without revision. In this assessment, qualitative data was not obtained from comments or suggestions for improvement from the validator. Then the results of the material validation test are presented in Table 5.

Table 5. Validity of GLOWASEA Edukit materials

No.	Validation Aspect	Score Gained (%)	Criteria
1.	Teaching Module Content	95.65	Very Valid
2.	Handout Material Content	90.00	Very Valid
3.	Worksheet Material Content	97.37	Very Valid
4.	Presentation	90.63	Very Valid
5.	Language	80.56	Very Valid
6.	Contextuality	87.50	Very Valid
7.	Concept Accuracy	100.0	Very Valid
8.	Pretest-Post-test Questions	87.65	Very Valid
Average		**91.17**	**Very Valid**

Based on the material validation data presented in the table, the GLOWASEA Edukits' equipment obtained a score of 80.56%, meeting very valid criteria for the linguistic aspect. This issue led to the products being prepared in clear language, easy

to understand, interactive, and aligned with the progress of students and the principles of Indonesian education. The importance of using communicative language in learning materials is to ensure that the information and instructions presented can be well understood by users [71]. Regarding contextual assessment, the GLOWASEA Edukits' equipment obtained a score of 87.50%, indicating its high validity. This is due to the selection of materials in the educational program that focus on topics relevant to real-life situations and require students to connect their knowledge with its application in everyday life. This follows the criteria for teaching modules, namely being relevant and contextual [72]. Overall, the GLOWASEA Edukits' equipment obtained an average score of 91.17% with highly valid criteria. In this validation test, qualitative data was also obtained based on responses and recommendations for improvement. The intended response and recommendations for improvement are that the identity of the educational unit in the teaching module has not been clearly outlined, so it needs to be corrected. Then the linguistic aspects of handouts and worksheets need to be reviewed because some sentences are written ineffectively or repeated words with multiple meanings that require revision. Based on the comments and suggestions, improvements have been made to the linguistic aspect following [71], which states that language in teaching materials must be appropriate for the reader and communicative. Therefore, all commands, instructions, and explanations must be clearly conveyed to avoid confusion. Apart from that, the pretest and post-test questions must be reviewed again for the sentences used. Some questions contain confusing or ambiguous sentences that need to be reviewed for standardized language. This follows [73], who stated that non-standard language should be avoided when formulating questions. Using formal language helps students better comprehend the questions. For this reason, adjustments are made to sentences so that students can clearly understand them.

The results of the validity and reliability tests for the questions are presented in Table 6. In the validity test, the T-table value obtained was 0.456. Because the T score obtained for all questions is greater than T-table (0.456), the question is deemed valid [60]. As for the reliability test of the questions, scores were obtained from Cronbach's Alpha of 0.759. The instrument is reliable if the Cronbach's Alpha value obtained is greater than 0.6 [59], [61]. Thus, the compiled questions are considered valid and reliable, making them suitable for assessing students' initial abilities and abilities after using Edukit GLOWASEA.

Table 6. Question validity test results

Question Number	T Score Obtained	Criteria
1	0.56	Valid
2	0.47	Valid
3	0.80	Valid
4	0.62	Valid
5	0.81	Valid
6	0.80	Valid

The next stage is the implementation stage. During this stage, university students accompany observers to help check the implementation of the activity and syntax stages arranged in the teaching module. Most of the learning syntax has been implemented perfectly, including in the preliminary stage, orienting students to problems, organizing students, guiding investigations, developing and presenting results, and

the closing stage. At the same time, the stages of analyzing and evaluating the problem have not been implemented perfectly yet. The time allocation needed for data collection is two meetings, each lasting 5 hours. The pretest was conducted outside of lesson hours for data collection due to the limited available time. During the initial meeting, the main topic of discussion was the impact of global warming on the oceans. Meanwhile, in the second meeting, the topics discussed included efforts to mitigate the effects of global warming and implement the post-test. There are 32 students in a class. They then formed eight groups, each consisting of four students. The learning syntax implemented is based on the continuous PBL model with five stages. In the first stage, students begin learning by observing graphs and formulating questions through the "Let's Observe!" and "Let's Ask Questions" activities. In the second stage, students can write down ideas about the problems formulated during the "Let's Discuss" activity. These two stages were completed during the initial meeting. In the third stage, students can experiment with Edukit GLOWASEA and record and evaluate information from available sources through the "Let's Investigate" and "Let's Write" activities. This investigation phase consists of two activities: an experiment using the GLOWASEA edukit and an investigation through references or literature studies. The research phase was conducted during both meetings. In the fourth stage, students can present the discussion/investigation results through the "Let's Be Creative" activity. In the fifth stage, students can communicate the results of their discussions and experiments through the "Let's Speak Up" activity. The final two stages were carried out at the second meeting. This last stage has not been implemented perfectly yet. This is because students are not actively engaging in responding to their friends' presentations. To prevent the presenter group from receiving questions or comments from other students. The implementation of the learning syntax arranged in the teaching modules is presented in Table 7.

Table 7. Implementation of activities in the teaching module

PBL Syntax	Percentage (%)
Introduction	100.0
Student Orientation to the Problem	100.0
Organizing Students	100.0
Guiding the Investigations	100.0
Developing & Presenting Results	100.0
Analyze and Evaluate the Problem	87.50
Closing	100.0

In addition, the worksheets that students have worked on are assessed to review the learning process. The average value of student activity in worksheets is presented in Table 8. This table indicates that the "Let's Be Creative" activity receives the highest average score. This issue affect the ability of student posters to meet the assessment criteria outlined in the rubric effectively. While the lowest average score is obtained in the "Let's Investigate" activity. This issue has led to students' answers on worksheets still needing improvement and being constrained by their limited time. Therefore, students need more time to perfect their answers in the activity column. For the "Let's Speak Up" activity, there is no scoring. In this activity, one group is randomly selected to present the results of their work in front of the class, while the other groups provide responses. Furthermore, the syntax that facilitates this activity is assessed to determine the learning outcomes by teachers and students.

Table 8. Average activity score on worksheets

PBL Syntax	Activity	Average Score (%)
Students Orientation to the Problem	Let's Observe!	84.38
	Let's Ask Questions!	84.38
Organizing Students	Let's Discuss!	81.25
Guiding the Investigations	Let's Investigate!	78.13
	Let's Write!	82.81
Developing & Presenting Results	Let's Be Creative!	87.50
Analyze and Evaluate the Problem	Let's Speak Up!	No Scoring

At this implementation stage, a limited effectiveness test is conducted through pretest and post-test assessments to evaluate the subject's critical thinking skills. Before calculating N-Gain as a measure of effectiveness, the normality of the data is tested. The obtained significance value for the pretest data is 0.146, and for the post-test data, it is 0.153. According to [60], if the significance value for the data normality test is greater than 0.05, then it is considered to be normally distributed. Thus, the data obtained from the pretest and post-test are normally distributed and can be used for the t-test and N-Gain analysis.

After the data is normally distributed, it can be used for a t-test to determine whether there is a significant difference between the values before and after using Edukit GLOWASEA. Results of a paired t-test show that there is an average increase between the pretest and post-test data from 9.13 to 14.28. When the signification level of the Paired t-test is 0.00 or less than 0.05, the null hypothesis (Ho) is rejected, and the alternative hypothesis (Ha) is accepted [62]. Hence, there is a notable difference in student scores before and after using Edukit GLOWASEA. Then, conduct the Normalized Gain test to assesses the effectiveness of Edukit GLOWASEA in enhancing students' critical thinking skills. The results are presented in Table 9. Overall, the average score obtained was 0.33, indicating moderate performance. The highest score is obtained on the interpretation indicator, and the lowest score is obtained on the inference indicator.

Table 9. Normalized gain test results

Indicators	Score Gained	Criteria
Interpretation	0.56	Moderate
Analysis	0.33	Moderate
Evaluation	0.30	Moderate
Inference	0.11	Low
Explanation	0.35	Moderate
Self-Regulation	0.32	Moderate
Average	**0.33**	**Moderate**

Facione and Gittens [7] define critical thinking as an individual's capacity to make judgments that entail interpretation, analysis, evaluation, and inference grounded in evidence, concepts, methodologies, criteria, and context. From this definition, Facione formulates several indicators of critical thinking skills: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Comparison of average

scores pretest and post-test based on indicators of critical thinking skills presented through bar charts in Figure 5.

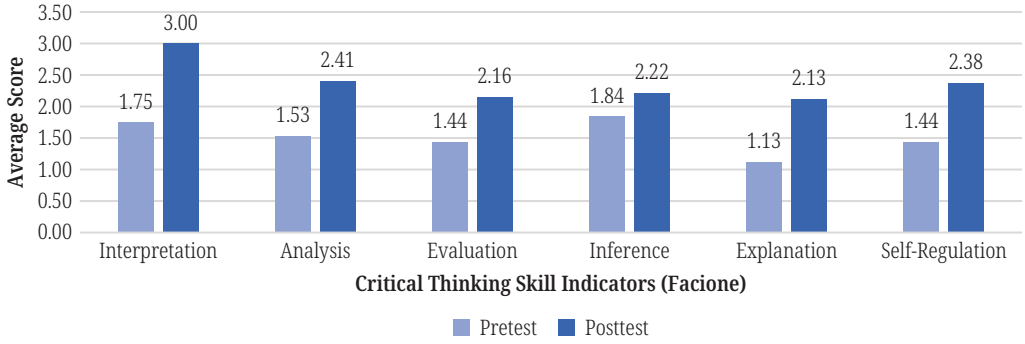

Fig. 5. Bar chart on the comparison of average pre-and post-test scores

When interpreting indicators, the sub-indicators used involve categorization and describing their significance. On this indicator, the average pretest yield is 1.75, while the average post-test result is 3. The test N-gain interpretation indicator scored 0.56, meeting moderate criteria. These matter-caused interpretation indicators have been trained through worksheets activities, namely "Let's Observe!" "Let's Ask Questions," and "Let's Investigate." In the "Let's Observe!" activity, students are asked to analyze the contents of the graph depicting changes in sea surface temperature and increased CO_2 emissions. This follows the sub-indicators describing significance, which means analyzing the content and purpose of the information conveyed in various forms of communication, such as graphics [7]. In the "Let's Ask Questions" activity, students are asked to formulate problems or questions related to graphics that they have understood in previous activities. In the "Let's Investigate" activity, students must understand the rules, procedures, and warnings in the manual for carrying out experiments using Edukit GLOWASEA. Both activities are based on categorization sub-indicators [7]. On interpretation indicators, students can comprehend and articulate the meaning or significance of various experiences, data, assessments, rules, procedures, and criteria [74]. By [75], one must be trained to interpret graphs in order to understand the physical aspects depicted in them and to enhance critical thinking skills.

In the analysis of indicators, the sub-indicators used assess ideas and detect arguments. On this indicator, the average yield pretest is 1.53, while the average yield post-test is 2.41. For the test N-gain, the analysis indicator obtained a score of 0.33 with moderate criteria. These indicators for analyzing matter have been developed through worksheets activities, namely "Let's Discuss" and "Let's Write". In the "Let's Discuss" activity, students are asked to identify issues related to the impact of global warming on the sea that will be the focus of discussion. This is done by assessing ideas through comparing several ideas in the form of questions or problems. In the "Let's Write" activity, students are asked to determine whether a statement in the references provided supports or opposes an opinion [7]. The same conclusion was drawn from the research conducted by [76], which suggests that students will enhance their skills in analyzing and investigating to find solutions through contextual problem. In this case, the contextual issues raised pertain to the impact of global warming on the oceans.

The sub-indicators used in the evaluation assess claims and arguments. On this indicator, the average yield pretest is 1.44, while the mean post-test results are 2.16. For the test N-gain, the analysis indicator obtained a score of 0.30 with

moderate criteria. This matter led to the training of evaluation indicators through worksheets activities, namely "Let's Write" and "Let's Speak Up". In the "Let's Write" activity, students need to evaluate whether the information provided is appropriate and pertinent to the discussed material. This follows the sub-indicator by assessing the relevance of the question regarding principles and information, as well as determining the admissibility of the evidence. In the "Let's Speak Up" activity, students are required to assess the arguments and opinions presented by the presenter group regarding the results of the discussion and determine whether the argument are based on valid references. This is consistent with the sub-indicator that evaluates arguments by determining whether they are based on solid or weak assumptions [7]. According to [77], students with critical thinking skills can evaluate arguments and opinions based on evidence. This was added by [78], who mentioned that students with critical thinking skills can assess the claims and opinions of others and consider the validity of other statements and representations.

In the inference indicator, the sub-indicators involving seeking evidence and exploring alternative possibilities. On this indicator, the average yield pretest is 1.84, while the average yield post-test is 2.22. For the test N-gain, the analysis indicator obtained a score of 0.11, meeting the low criteria. These matter-caused inference indicators have been trained through Edukit GLOWASEA and worksheet activities, specifically through the "Let's Investigate" program. In the "Let's Investigate" activity, students were asked to search for evidence-based experiments using Edukit GLOWASEA at the first meeting and to list various measures that could be implemented to prevent or mitigate the effects of global warming at the second meeting. Successively, these two steps follow the sub-indicator of seeking evidence, which involves identifying premises that require support and formulating a strategy to find information that can offer support, and the sub-indicator of considering alternatives, which involves creating multiple plans to achieve goals [7]. Inference indicators have been trained, but the criteria n-gain obtained still needs to be higher. This can happen because students find it challenging to draw conclusions from references in learning activities. So, it takes quite a long time [79].

In the explanation or argument indicators, the sub-indicators convey results and present arguments. On this indicator, the average pretest yield is 1.13, while the mean post-test results are 2.13. For the test N-gain, the analysis indicator obtained a score of 0.35 with moderate criteria. This matter has been addressed through explanatory indicators that have been incorporated into worksheet activities, namely "Let's Be Creative" and "Let's Speak Up". In the "Let's Be Creative" activity, students are asked to compile the results of their investigations based on experiments and findings from literature studies from references. This follows the sub-indicator of conveying results, namely producing statements, descriptions, and accurate representations of the results of one's reasoning. In the "Let's Speak Up" activity, students are required to justify arguments with reasons derived from the outcomes of group work. This follows the sub-indicator presenting arguments, specifically giving reasons for accepting a claim [7]. The same idea was expressed by [80], defining the explanation indicator as the ability to logically persuade the conclusions of an argument. Therefore, students can express reasons for their work during presentations.

In the context of regulation or self-regulation, the sub-indicator utilized is self-assessment. On this indicator, the average yield pretest of 1.44, while the mean post-test results are 2.38. For test N-gain, the analysis indicator obtained a score of 0.32 with moderate criteria. This matter led to the training of self-regulation indicators through worksheet activities, specifically "Let's Be Creative" and "Let's Speak Up." In the "Let's Be Creative" activity, students are required to organize themselves through

group work activities and contribute according to their abilities. In the "Let's Speak Up" activity, students are required to understand their abilities so that they can position themselves effectively when presenting the results of their group work. Both follow the sub-indicators of self-assessment, namely conducting self-assessments objectively and carefully [7]. The same idea was expressed by [81], stating that self-regulation is a skill involving monitoring thinking processes and elements used in problems-solving.

Based on the indicators of critical thinking skills mentioned, the test acquisition N-gain is the highest in the interpretation indicator. It is causing activity on worksheets that focus on training more interpretation indicators than other indicators. Saidah [82] states that when students repeatedly learn about specific abilities, they will master these skills. Thus, since interpretation indicators are developed through three activities, which are more numerous compared to other indicators, students will acquire these skills more effectively than others. At the same time, the test acquisition N-gain was the lowest when measured on the inference indicator. Inference indicators on worksheets activities are only addressed through one "Let's Investigate" activity. Therefore, the inference indicators require enhanced training in learning activities using the GLOWASEA Edukit media. When assessing students' worksheets, the activity "Let's Investigate" receives the lowest score compared to all other activities. Due to time constraints, we must proceed to the next stage so that learning can be carried out according to the prepared scenario. As a result, students still need to provide more accurate answers. Based on the teacher's practicality test, the acquisition of the interpretation indicator is higher than that of the inference indicator. Based on research by [11], students' inference skills are limited because they have not yet learned to recognize them in order to draw conclusion. In line with this, Hidayati [79] states that the inference indicator of critical thinking skills requires students to be able to draw conclusions information and articulate in sentences that align with their knowledge. To overcome these obstacles, the teacher must intensify supervision and guidance of students to ensure that the learning process proceeds as planned and achieves the learning objectives.

The GLOWASEA Edukit and its equipment have been tested for practicality by science teachers and students. The results of the practicality test have been presented in Table 10. In the practicality test conducted by the teacher, qualitative data was also gathered in the form of suggestions for improvement. The advice is to replace the cover paper of the edukit box with thicker paper. In addition, the pages in the teaching modules should be consistently in portrait orientation to enhance reliability, and the language structure of the worksheets needs to be simplified. Another suggestion is to replace the edukit component packaging with waterproof packaging because all the experiments provided by edukit use water as the experimental material. The packaging for the Edukit components is made of duplex cardboard, which is not waterproof. Therefore, there is a possibility that the packaging will be quickly damaged if exposed to water [83]. In this practicality test, students also provide suggestions, such as adding more colors to the handout cover to make it more attractive, and incorporating ice-breaking activities and prizes during learning sessions.

Table 10. Teacher and student practicality test results

Data	Score Gained (%)	Criteria
Teacher Practicality	91.22	Very Practical
Student Practicality	90.04	Very Practical
Average	**90.62**	**Very Practical**

Firmadani [21] states that learning media refers to all physical or technical elements utilized in teaching and learning activities to facilities teachers in conveying material more effectively and accomplishing predetermined learning objectives. This has supported the development of the GLOWASEA Edukit, as evidenced by the students' learning activities and the positive responses regarding the developed learning kits. In general, when assessing students' learning outcomes based on indicators of critical thinking skills, there has been a noticeable and a significant increase in learning outcomes. By discussing research results, relevant theories, and sources, it can be concluded that the GLOWASEA Edukit has been effective in enhancing students' critical thinking skills in science education particularly in the context of global warming. In addition, Edukit GLOWASEA and its equipment have been deemed effective and practical for learning purposes.

4 CONCLUSION

The development of PBL-based GLOWASEA Edukit media for the topic of global warming has successfully improved students' critical thinking skills. Edukit and its equipment have been validated by media experts and material experts, meeting the criteria of being highly valid. Practicality tests conducted by teachers and students showed that the GLOWASEA Edukit and its equipment were highly practical. Statistical analysis, including paired t-tests and N-gain t-test, revealed a significant difference before and after using GLOWASEA Edukit, with a moderate N-gain. In conclusion, GLOWASEA Edukit is valid, practical, and effective learning tool for enhancing students' critical thinking skills.

5 ACKNOWLEDGMENTS

We acknowledge the State University of Malang for funding the UM PNBP thesis grant with contract number 5.4.470/UN32.20.1/LT/2023. Thank you to Isnanik Juni Fitriyah, S.Pd., M.Sc., as the material expert validator, Dr. Dian Nugraheni, S.Pd., M.Sc., as media expert validator, Zuliya Indah K., S.Pd., Abdul Mu'iz, S.Si., M.Pd. as a science teacher and Umroh Mahfudhoh, S.Si. as Deputy Head of Madrasah Curriculum at MTs Negeri Batu who has assisted and supported this research and all students in class VIII-C, VIII-G, and VII-D MTs Negeri Batu who have contributed to this research.

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