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Development of Google Sites E-Module Based on PBL on Respiratory System to Improve Critical Thinking Skills of Middle School Students

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Abstract

Critical thinking skills are essential for students, yet junior high school students often show low levels of these abilities. Previous studies using Google Sites did not integrate the Problem-Based Learning (PBL) model or focus specifically on respiratory system content and critical thinking. This study aims to develop a PBL-based Google Sites e-module on the respiratory system that is valid, practical, and effective in improving critical thinking skills. The development followed the ADDIE model: analyze, design, develop, implement, and evaluate. Data were collected through questionnaires and tests and analyzed descriptively to assess validity, practicality, and effectiveness. Validation results showed the material was highly valid (84.89%) and the media valid (79.47%). Practicality tests based on teacher and student assessments resulted in scores of 94.68% and 92.71%, respectively, indicating the media was very practical. The effectiveness was supported by an independent sample t-test showing significant differences in critical thinking scores between experimental and control classes. The average N-Gain score of 0.67 in the experimental class indicated a moderate improvement, and a Cohen's d effect size of 1.21 suggested a large impact. This e-module is valid, practical, and effective for science learning, particularly in supporting teachers to implement student-centered learning that fosters critical thinking.

Keywords: E-module, Google Sites, Critical Thinking, PBL

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INTRODUCTION

Critical thinking is a have to-have work ability for fixing troubles, collecting proof, and comparing facts (Song et al., 2024). Critical thinking is the principle goal predicted in twenty first-century schooling (Leibovitch et al., 2024). Precise critical thinking competencies will help every step (Susanti et al., 2023). However, in Indonesia the crucial thinking abilities of junior excessive faculty students are nevertheless highly low. tested by way of the consequences of the program for international student assessment (PISA) in 2022, assessing that 15-yr-antique students in Indonesia still have poor critical wandering capabilities, and college students simplest attain degrees 1-2 of 6 tiers of questions (OECD, 2024). The effects of studies byAsih et al. (2022), additionally display that scholars' abilities are still low, characterized by passivity during observation and a lack of courage to express opinions. Other research states that secondary students in Indonesia have low critical thinking skills. In class discussions, students listen more than ask question. This is likely due to the lack of critical thinking exercises in learning (Nia et al., 2022).

Respiratory system material is material that discusses a group of organs responsible for the process of exchanging carbon dioxide and oxygen gases in the blood (Zendrato et al., 2022). Material related to the respiratory system, especially respiratory system disorders, is important to learn because it is relevant to current conditions. However, many students find it difficult,

this is evidenced in the research of Mufidah and Habibi (2022), which shows that 57.3% of students find it difficult, especially those related to respiratory diseases related to everyday life. other research also states that respiratory system material is hard for college students to recognize, as evidenced by means of the results of each day exams that display most college students get hold of scores which can be beneath the KKM of 76, with a low class classical completeness cost of 43.75 (Prastiyo et al., 2023).

Based on the results of the needs analysis at one of the Junior High Schools in Paciran Lamongan and MTsN in Batu City, it is known that students have problems with information on respiratory system material in addition to critical thinking. The selection of these 2 schools was based on different school backgrounds, namely SMPN Paciran Lamongan (rural area) and MTsN Batu (urban area). The selection was intended to obtain an initial picture of the challenges of science learning and the needs of digital media from two contrasting types of contexts, these findings were used as a basis for designing flexible and responsive e-modules. With the results at SMPN Paciran Lamongan, 68% of students stated that this material was difficult, and the same percentage also had difficulty in critical thinking. As many as 65% of students stated that the media often used were textbooks. Most (65%) expressed interest in using e-modules with respiratory system material that could help improve critical thinking. Likewise at MTsN in Batu City, where passive teacher-centered learning is the norm. Although up to 58% of students are interested in using e-modules, and 15% are very interested in doing so, lectures and textbooks remain the main media used in this institution. Both schools agreed that students' critical thinking skills are still lacking and they need educational materials that can improve those skills. Creating media that can improve students' critical thinking skills is needed in this situation..

According to previous studies, various instructional media have been developed to improve students' critical thinking skills. For instance, (Susanti et al., 2023) designed Google Sites e-modules using a discovery learning model, which supported structured and interactive learning and showed positive effects on students' critical thinking. However, their study did not integrate the Problem-Based Learning (PBL) approach, which emphasizes real-life problem solving and collaborative inquiry. In another example, Ratnawati et al. (2020) developed question card media with a PBL model for geometry material, successfully stimulating students' critical thinking. Nonetheless, the media was not digital-based, limiting accessibility and interactivity, it was also not explained what critical thinking indicators were used in this research to evaluate. In line with that, Rani et al. (2024), stated that interactive media with respiratory system problem solving can help improve students' critical thinking skills. However, their research also did not utilize the learning model in it to achieve this goal and used critical thinking indicators according to Faction (2015) instead of Ennis' critical thinking indicators (1985).In addition, learning models also play a very important role in various learning systems. Errors in model selection will make training ineffective (Putri, 2022). PBL itself has proved effective in improving students' capacity for critical thought (Komariah et al., 2024). Problem-based learning, or PBL, is a student-centered educational strategy that encourages collaborative projects. When employing this approach, students must finish open-ended, single-answer issues (Y. Liu & Pásztor, 2022). Students' capacity to recognize issues, evaluate data, and develop original solutions can be enhanced by problem-based learning (Wardani, 2023). Additionally, Chrisdiyanto and Hamdi (2023), claimed that the problem-based learning strategy improves critical thinking skills. Waruwu et al. (2022) created PBL-based modules for respiratory system content, yet their product did not utilize web-based platforms like Google Sites and focused mainly on cognitive outcomes rather than explicitly aligning with critical thinking indicators.

These studies reveal a clear gap: no previous studies have combined PBL and Google Sites for respiratory system content while using Ennis' critical thinking indicators as a design and evaluation framework. This integration is important because it not only supports content

delivery but also fosters students' reasoning, evaluation, and inference skills through structured problem-solving activities.

The pedagogical rationale for combining PBL with Google Sites in this study lies in their complementary strengths. PBL facilitates in-depth inquiry-based learning, while Google Sites enables interactive, media-rich, and accessible digital delivery (Ernest & Putra M, 2023). Students will be more actively involved in their learning if e-learning modules are added (Logan et al., 2021). By integrating the two, this study creates a learning experience that encourages higher-order thinking and supports it with digital tools that are easily accessible to students. The instructional design rationale for integrating PBL with Google Sites is supported by Nurdin et al., (2023), who employed an ADDIE-based R&D approach in developing digital teaching materials. Their study demonstrates that Google Sites effectively supports each phase of the PBL framework—ranging from problem identification to reflections—by providing a flexible, collaborative platform that enhances critical thinking in mathematics at the MTs level (Wahyuni et al., 2024). A systematic review and meta-analysis by the Digital Health Education Collaboration (2019) found that Digital PBL (DPBL) significantly improved student learning outcomes (standardized mean difference ≈0.67–0.94) compared to traditional methods, especially when problems were presented digitally. The study also explained how digital technology supports each stage of PBL from a pedagogical perspective, not just a technical one (Car et al., 2019). A meta-analysis by Wiratama et al. (2023), which examined 21 studies between 2017–2024, showed that PBL consistently improved students' critical thinking skills in science learning with a significant effect size. The novelty of this study lies in the effort to address this gap by developing a Google Sites-based e-module on the respiratory system material that applies the PBL model and is explicitly structured around Ennis' (1985) critical thinking indicators. This innovation provides a solution that is pedagogically grounded, technologically accessible, and aligned with the curriculum that has not been explored in previous research.

The goal of this study is to create a Google Sites E-Module on respiratory system content using PBL that is feasible, valid, and practical, and can determine efficiency of improving critical thinking skills of junior high school students. The research focuses on human respiratory system content from the Merdeka Curriculum and uses the PBL model combined with Ennis' (1985) critical thinking indicators: elementary clarification, strategy and tactic, basic support, inference, and advanced clarification. These indicators are suitable for junior high school students as they emphasize explanation, evaluation, and logical reasoning, which are essential for science learning. Ennis' (1985)critical thinking indicators were chosen because they were designed for elementary to secondary education levels, emphasizing the aspects of clarification, inference, and evaluation which are appropriate for the cognitive stage of junior high school students (Ennis, 1985). In addition, this study considers the challenges of implementation in the classroom, such as limited learning time, readiness in using digital media. With this in mind, this e-module is designed to be relevant and adaptive to be implemented in various school conditions, both those with limitations and those that are technologically ready.

METHOD

This study applies the research and development (R&D) research method to develop the Google Sites e-module product. This study refers to the ADDIE development model developed by Robert Maribe Branch in 2009 (Branch, 2009). The ADDIE model was chosen because the general framework is structured, flexible, easy to use, and supports student-focused learning and ongoing evaluation (Safitri & Aziz, 2022). Another advantage of the ADDIE model is that it has a structure that can help student-focused teaching. The ADDIE model is composed of five stages including analysis, design, development, implementation, and evaluation (Fitriani & Indriaturrahmi, 2020). The effectiveness test was carried out at the implementation stage by

conducting a trial using a quasi-experimental research design, namely a non-equivalent control group design, involving two classes: a control class and an experimental class.

Analyze

The first stage is analysis, this analysis is used to find out the various needs in learning at SMP Negeri Lamongan Regency and MTsN Batu City. At this stage, the methods used were interviews with 8th-grade science teachers, questionnaires for 8th-grade students, and literature studies. Literature study. According to Branch, (2009), the analysis stage in the ADDIE model aims to identify and validate performance gaps in learning. At this stage, identification of the factors that cause the gaps, confirmation of the audience, confirmation of the intended audience, and analysis of the resources needed. Therefore, in this study, a needs analysis was conducted in two schools to obtain a more comprehensive picture of the learning conditions in the field. By comparing the results from two schools, by comparing the results from the two schools, the needs identified can better represent the broader conditions and increase the validity of the findings in the e-module development. Increase the validity of the findings in the development of e-modules. Analysis stage qualitative and quantitative data were obtained. Student needs analysis questionnaires provide quantitative data, and interviews with teachers provide qualitative data. The data was analyzed by calculating the average value of the quantitative data, then the results were converted into a percentage to determine the needs of the school.

The type of interview used in this study is a semi-structured interview to conduct the interview. During the interview, the researcher created a research instrument in the form of written questions, which were then answered by the informants, who in this study were the science teacher of class VIII E at SMP Negeri Lamongan Regency and the science teacher of class VIII K at MTsN Batu City. And using a closed questionnaire that will be given to class VIII students to identify student needs in learning. This analysis showed that at SMPN Lamongan Regency, 68% of students stated that the respiratory system material was difficult, and the same percentage also had difficulty in critical thinking. This is reinforced by the statement of the science teacher who stated that students have low critical thinking skills as evidenced by students who tend to be passive during discussions and the value of this material has not reached what is desired, this low result is due to the low understanding of students on the material. As many as 65% of students stated that the media commonly used was textbooks. Students' experiences during science learning associated with critical thinking skills 45% of students stated rarely and 10% of students stated never. Most (65%) students stated that they were interested in using e-modules on the respiratory system material that could help them improve their critical thinking. Likewise with MTsN in Batu City, where learning tends to be passive and teacher-centered. As many as 58% of students were interested and 15% were very interested in using e-modules, but 58% of students stated that in this school the method often used was still lectures, and textbooks were the main media. Both schools agreed that students' ability to think critically was still low. According to Putri (2022), the learning model plays a very important role in various learning systems. Choosing the wrong model will make learning ineffective (Putri, 2022). This statement is also supported by Ernest and Putra M (2023), who stated that 21st-century learning demands innovation by utilizing technology as a learning resource. The integration of technology in education plays an important role in improving skills. By getting used to using digital teaching materials, students can more easily access teaching materials anytime and anywhere. Technology also supports collaboration between teachers and students and clarifies learning materials.

Design

The second stage is design. This includes constructing an electronic module with key components such as a home screen, CP-based learning objectives, usage instructions, a concept map, and two learning activities aligned with the PBL syntax. The first activity focuses on the

structure and function of the respiratory organs and the breathing mechanism, while the second explores respiratory system disorders and the dangers of smoking.

To ensure instructional scaffolding, each activity is sequenced to gradually build students' understanding—from observing real-life problems (apperception video), to investigating causes, drawing conclusions, and engaging with supporting materials such as videos, illustrations, and guiding questions. This approach has been shown to enhance understanding and reduce cognitive load when combined with technology-enhanced supports (Kaldaras et al., 2024), as instructional support is progressively reduced as students gain independence.

Additionally, the content is organized into focused and chunked sections, using simple language and visual support. Recent research has shown that segmenting multimedia content can significantly reduce cognitive load and improve learning outcomes in students (Liu, 2024). The design also leverages students' prior knowledge by presenting materials through familiar contexts—such as daily breathing and air pollution. Features like Quizizz-based assessments, reflective prompts, and a glossary are included to support deeper comprehension while preventing cognitive overload.

Develop

The third stage is development, at this stage the e-module is developed according to the design results made, including the creation of e-modules on Google Sites such as creating pages according to the structure designed at the design stage, compiling and uploading text content, materials, images, adding interactive links to make it easier for students. Furthermore, the preparation of activities 1 & 2 based on PBL is carried out to help students solve real problems related to the respiratory system. Each stage in the PBL syntax is equipped with questions or activities integrated with Ennis' critical thinking indicators designed to improve students' critical thinking skills. The mapping between the PBL stages and Ennis' indicators is presented in Table 8. Specifically, the first stage (orienting students to the problem) corresponds to elementary clarification; the second stage (organizing students for learning) is aligned with strategies and tactics; the third stage (guiding individual or group investigations) relates to basic support; the fourth stage (developing and presenting the work) corresponds to advance clarification; and the fifth stage (analyzing and evaluating the problem-solving process) is aligned with inference. The e-module also includes apperception activities and explanatory materials that contextualize respiratory system concepts in a way that is accessible to students.

To support procedural fidelity in the application of the Problem Based Learning (PBL) model, a usage guide has been prepared which is part of the e-module. This guide contains a clear explanation of the PBL syntax and its application in each activity, the guide serves as a reference for teachers to apply the PBL approach consistently according to the plan.

Table 1. Percentage Criteria for Validity

Score	Criteria
80% - 100%	Very Valid
66% - 79%	Valid
56% - 65%	Moderately Valid
40% - 55%	Less Valid
30% - 39%	Very Poorly Valid

Source: (Arikunto, 2013)

The e-module has been developed and the media validation test process has been carried out, the material validation test on the e-module by the media and material expert validator by the lecturer of Malang State University, then the readability test. In this stage, two data were obtained, the first data is qualitative data obtained from the results of comments from the media and material expert validator through the media and material validation sheet, as well as the results of student comments through the readability test sheet. The second data is quantitative data obtained from the media and material validation values by the validator, as well as the

results of the student readability test. In this assessment, a Likert scale was used. The data was analyzed by calculating the average value of the quantitative data, then the results were converted into a percentage to determine the module's eligibility. The assessments from the experts for all aspects assessed are provided in the form of a table to produce an average score. Table 1 shows the results used to determine the product validity category.

Based on these criteria, the product is said to be valid if it gets a score of 66%-79%. To validate the evaluation materials using the Guttman scale, which assigns a score of 1 to "Yes" and a score of 0 to "No". This study did not apply statistical reliability analysis such as Cronbach's alpha due to the limited sample and developmental design. Instead, expert judgment was used as a widely accepted approach to ensure instrument consistency and relevance, especially in educational research where formal reliability testing may be constrained (Sugiyono, 2013).

The overall e-module media validation results showed an average score of 79.47% in the valid category. In the aspect of the e-module display, it received a score of 82.50% including a very valid category; in the aspect of content presentation, it received a score of 87.50% including a very valid category; the technical aspect received a score of 75% including a valid category; and in the language aspect, it received a score of 75% with a valid category. However, there were criticisms and suggestions from validators on the language aspect that punctuation marks at the end of sentences need to be considered, word redundancy needs to be avoided, and the addition of persuasive words, so revisions are needed. By research which states that use correct writing and punctuation to avoid ambiguous meaning (Eliyani & Faizin, 2024). Furthermore, in the aspect of e-module display, the validator assessed that some parts are less symmetrical between right and left, and less neat in the arrangement of e-modules, so there are parts that need to be improved in the color combination of background and content. Therefore, the validator suggested that the e-module be revised and the less neat parts can be tidied up as well as the color selection and sentence arrangement so that critical thinking skills based on the indicators are visible.

The results of the e-module media validation showed that the content presentation aspect scored 87.50% (very valid category). In this aspect, the alignment with problem-based learning (PBL) syntax and how the e-module encourages students to think critically have been assessed in the validation instrument. The results of this validation indicate that the e-module has been designed to provide problem-based learning experiences, where students observe respiratory system problems, formulate questions, analyze information, and conduct investigations based on credible sources such as AR Innerbody Anatomy - Respiratory System and simple practicum. In addition, at the investigation and solution development stage, students are invited to conclude the impact of air pollution and cigarette smoke on respiratory health. Thus, the high validity in the content presentation aspect indicates that this e-module has met the standards of designed to integrate the PBL approach and critical thinking skills as assessed in the validation instrument. Overall, this e-module received a valid score to be applied in learning respiratory system material. The following table displays the e-module validation value results:

Table 2. E-module Media Validation Results

Assessment Aspect	Assessment Score (%)		Average (%)	Description
	Validator 1	Validator 2		
E-module Display Aspect	85.00	80.00	82.50	Very Valid
Content Presentation Aspect	91.66	79.1	85.41	Very Valid
Technical Aspect	75.00	75.00	75.00	Valid
Language Aspect	75.00	75.00	75.00	Valid
Average			79.47	Valid

The e-module material validation examination yielded an overall score of 84.89%, which is categorized as "very valid." The material feasibility aspect earned a score of 81.25% (very valid category), while the material presentation aspect received 83.33% (very valid category).

The language aspect attained a score of 75%, placing it in the "valid" category, and the truth of the concept aspect achieved a perfect score of 100% (very valid category).

As with the media validation, formal statistical reliability analysis was not performed on the material validation due to the study's design characteristics**.** Instead, expert validation served as a valid and widely recognized method to establish the credibility of the instruments (Sugiyono, 2013). Suggestions were made to refine language style to improve persuasiveness and interactivity in order to better reflect critical thinking indicators. Overall, the material in this e-module received a very valid score to be applied in learning the material of the respiratory system. The following table displays the findings of the e-module material validation scores:

Tabel 3. Results of E-module Material Validation

Assessment Aspect	Assessment Score (%)		Average (%)	Description
	Validator 1	Validator 2		
Aspects of Material Feasibility	87.50	75.00	81.25	Very Valid
Material Presentation Aspect	87.50	79.00	83.33	Very Valid
Language Aspect	75.00	75.00	75.00	Valid
Concept Correctness Aspect	100.00	100.00	100.00	Very Valid
Average			84.89	Very Valid

The Google Sites e-module readability test conducted at one of the junior high schools in Malang City obtained an average result of 92.65 including a very good category. The language aspect obtained an average score of 90.27%, including a very good category, then for the presentation aspect obtained an average score of 94.44, including a very good category. The material aspect obtained an average score of 93.75% including a very good category. Overall, this e-module scored very well to be applied in learning respiratory system material. The results of the e-module readability test scores are presented in Table 4.

Table 4. E-module Readability Test Results

Assessment Aspect	Assessment Score (%)						(%)	Description
	C	SE	I	R	T	SW		
Language Aspect	100.00	83.33	91.66	100.00	97.00	91.66	90.27	Very Good
Presentation Aspect	91.66	100.00	91.66	91.66	91.66	100.00	94.44	Very Good
Material Aspect	100.00	100.00	87.50	100.00	75.00	100.00	93.75	Very Good
Average							92.82	Very Good

Implement

The fourth stage is implementation, at this stage the Google Sites e-module was implemented in class VII B at one of Malang's junior high schools. The use of the PBL-based Google Sites e-module was carried out for 5 lesson hours (JP). Students use the e-module that has been developed to follow learning with the problem based learning (PBL) model. After the learning process, teachers and students fill out a practicality test questionnaire. Practicality is one of the main criteria in assessing the quality of learning media that is always considered at every stage of development, whether the media is easy to use and according to needs or not (Faradayanti, 2020). Qualitative data was obtained through feedback and suggestions from teachers and students collected through the practicality test sheet. Meanwhile, quantitative data was obtained from the calculation of the practicality test scores given by teachers and students using a Likert scale. The percentage of practicality level was calculated to analyze the quantitative data. The e-module practicality test was conducted using a response questionnaire to the e-module that had been developed. The results of this test were used to determine the level of product practicality, which can be seen in Table 5.

This implementation stage also employed a quasi-experimental study design with two classes—the control and experimental classes—and a non-equivalent control group design,

class VII A as the control class and class VII B as the experimental class. To determine whether baseline conditions differentiated the experimental and control groups, two groups were tasted prior to the experiment in this design (Sugiyono, 2013). This design was chosen because it aligns with the study's goals, which are to ascertain how well Google Sites e-module media may enhance students' critical thinking abilities.

Table 5. Percentage Criteria for Practicality

Score	Criteria
0% - 20%	Very impractical
21% - 40%	Not practical
41% - 60%	Moderately practical
61% - 80%	Practical
81% - 100%	Very practical

Source: (Riduwan, 2013)

In the experimental class, students were grouped into small groups (five to six students per group). They worked together in completing tasks and questions in Activity 1 and Activity 2. At the first meeting, students focused on working on activity 1 which focused on the structure, function, and mechanism of breathing in the respiratory system material. Then at the second meeting continued working on activity 2 which focused on the dangers of smoking, and respiratory system disorders due to smoking.

This effectiveness test was carried out by comparing pretest and post-test results using 5 questions to measure critical thinking indicators according to Ennis. First, the pretest and posttest data were analyzed using the Shapiro-Wilk normality test; if the significance value is more than 0.05 the data is considered normally distributed. Followed by the homogeneity test. In addition, the Independent sample t-test was used to determine the significance of the difference in the results of the experimental and control classes. If the significance value is 0.000 <0.05, then there is a significant difference between the two results (Galih W. et al., 2022). In research involving experimental groups and control groups, the N-Gain Score test can be applied if there is a significant difference between the average posttest scores of the experimental group and the control group, as proven by an independent sample t-test (Fahruddin et al., 2022).

Table 13 shows the outcomes of the N-Gain computation. In accordance with the N-Gain level criteria proposed by (Hake, 1999), the classification is presented in Table 6.

Table 6. N-Gain Percentage Criteria

Score	**Criteria**
$g > 0.7$	HIgh
$0.3 \leq g \leq 0.7$	Medium
$g < 0.3$	Low

Cohen's d effect size is used to determine how much influence learning using Google Sites e-modules has on students' critical thinking based on a comparison of pre-test and post-test scores. This value indicates the level of effectiveness of the intervention, which is categorized into three: small, medium, and large effects. With the following formula.

$$d = \frac{M_1 - M_2}{SD_{gab}}$$

Description:
M_1 = Average post-test score
M_2 = Average pretest score
SDgab = Combined standard deviation (J. Cohen, 1988).

Evaluate

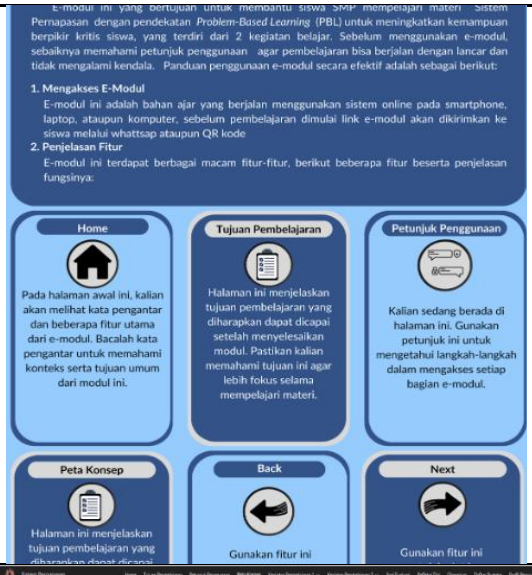
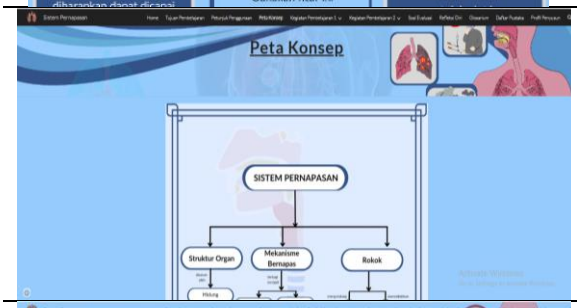
Evaluation was conducted formatively at each stage of e-module development to ensure the quality of the products produced. Revisions are made based on input from validators and users, especially at the validation stage. Evaluation in learning product development is important to adjust the product to the needs of users (Safitri & Aziz, 2022).

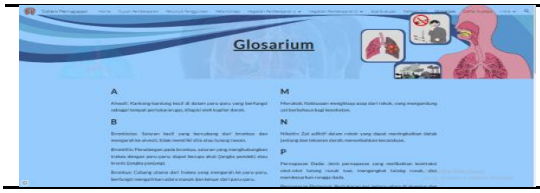
RESULTS AND DISCUSSION

This research obtained a product in the form of e-modules based on problem based learning (PBL) with the Google Sites platform developed on the material of the respiratory system. This product is prepared by paying attention to the structure and content of the e-module in accordance with 21st century learning. The specifications of the products produced can be seen in the following table.

Table 7. E-Module specifications

Picture	Explanation
	Cover: This page displays the initial view of the e-module containing the title of the material, illustrations related to the respiratory system, and various main features. At the bottom there is a foreword that provides an overview of the contents and objectives of the e-module. Main Features: This e-module is equipped with various learning support features including: 1. Learning objectives, 2. Instructions for use, 3. Concept maps, 4. Learning activities 1 and 2, 5. Evaluation questions, 6. Self-reflection, 7. Glossary, 8. Bibliography, and 9. Author profile. All of these features can be accessed interactively through the Google Sites platform
	Learning Objectives: This page contains learning outcomes, learning achievement indicators, and learning objectives that students want to achieve after studying the material in this e-module.

Picture	Explanation
	Instructions for Use: This page provides an explanation of the flow of using the e-module, including available features such as home, learning objectives, instructions for use, concept maps, and back, next, and other navigation. This explanation aims to ensure that students understand how to access and use the e-module, and support smooth learning.
	*Concept Map: This e-module presents a flowchart of the Respiratory System material. This concept map is designed to help students understand the relationship between key topics, such as organ structure, breathing mechanisms, and respiratory system disorders. This visual display makes it easier for students to see the relationship between sub-materials as a whole before delving into each part in the learning activities.*
	Learning Activity 1: This page contains learning activities that focus on the material of the structure, function of the respiratory system, and breathing mechanisms. Presented in 3 main parts: apperception, discussion, and materials, which are marked with attractive visual icons. In this discussion section, a problem-based learning model is used that is integrated with Ennis' critical thinking indicators.
	Learning Activity 2: This page contains learning activities that focus on the material of respiratory system disorders and the dangers of smoking. Presented in three main parts: apperception, discussion, and material, which are marked with attractive visual icons. In this discussion section, a problem-based learning model is used that is integrated with Ennis' critical thinking indicators.
	Evaluation Questions: This page provides practice questions in the form of interactive quizzes (using Quizizz) to test students' understanding of the respiratory system material.
	Self-Reflection: This page provides space for students to evaluate their understanding and learning experiences personally after studying the respiratory system material.

Picture	Explanation
	Glossary: This page displays a list of important terms and their meanings to help students understand the vocabulary in the respiratory system material

The next step, after describing the structure and features of the e-module is to analyze how the PBL syntax in this e-module accommodates the critical thinking indicators according to Ennis. Table 8 below shows the grouping of each problem-based learning (PBL) syntax with the targeted critical thinking indicators.

Table 8. Grouping PBL Syntax with Critical Thinking Indicators in Experimental Classes

No	PBL Syntax	Critical Thinking Indicators	Critical Thinking Sub-Indicators	Activity
1	Orientation of students to the problem	Elementary Clarification	Formulate questions and ask questions related to a statement	Individually, students watch a news video about respiratory system problems, then formulate questions for further study
			Analyze arguments and respond to a statement.	Students are asked to individually express their initial opinions regarding how air pollution can affect the organs of the respiratory system based on the knowledge they already have.
2	Organizing students to learn	Strategies and tactics	Interacting with others.	Students gather in groups to discuss and seek valid sources of information regarding respiratory health issues.
			Determining action	In groups, students discuss to determine the initial steps before carrying out practical activities, including dividing tasks such as recording, researching sources, and reporting results.
3	Guiding group or individual investigations	Basic support	Considering the reliability of sources	In groups, learners analyze activity 1 using Augmented Reality (AR) Innerbody Anatomy - Respiratory System, and activity 2 analyzes by considering prior knowledge and considering the reliability of information sources, according to the direction of trusted sources.
			Understand and evaluate observation reports.	Students perform a simple lung model practicum and collect information obtained in activity 1, and in activity 2 by analyzing cases about the respiratory system.
4	Analyze and evaluate problem-solving	Advance Clarification	Identify terms in a definition.	In their groups, students carry out simple lung lab work, discuss the results, and relate the lab findings to the material they have studied.
			Assess definitions from various perspectives.	Students develop new definitions or understandings of the concept of the respiratory system based on the results of group discussions. This process encourages negotiation of meaning and shared understanding among members.
5	Develop and present work.	Inference	Making deductions, considering the results of deductions. And	Students and group analyze and evaluate the impact of poor air quality and cigarette smoke on respiratory health and conclude the symptoms and preventive measures to protect the respiratory system.

No	PBL Syntax	Critical Thinking Indicators	Critical Thinking Sub-Indicators	Activity
			inducing and considering the results of induction.	
			Making and evaluating conclusions based on the information obtained	Each group make conclusions related to the impact of air pollution and cigarette smoke on public respiratory health.

In the implementation of learning, there were students with low prior knowledge who had difficulty navigating the Google Sites page at the beginning of learning. This was conveyed in an open response: "I was a bit confused at first opening the link and moving from page to page, but after it was explained I understood". Students needed a little time to adapt. However, after a brief orientation and guidance, students showed increased engagement. Regarding group dynamics in PBL learning, students with high prior knowledge tend to be discussion leaders and help other group members, while students with lower abilities act as observers and complements.

Furthermore, a practicality test was conducted to assess the extent to which this e-module can be used effectively in the classroom. The practicality test aims to assess the extent to which certain based e-modules can be used effectively. This level of practicality can be measured through interviews/questionnaires, as well as observations of teacher and student activities, then compared with practicality standards. (Fatmianeri et al., 2021). Researchers in this study assessed the practicality of e-modules using a response questionnaire. Using very practical criteria, the teacher's practicality test yielded an average score of 94.68%. Considering the outcomes of the teacher's practicality test survey, this Google Sites e-module media in various aspects including display, material, technical, and language aspects are very practical to use in learning the respiratory system. The teacher also provided input for the background color section and a few technical improvements in the evaluation questions section.

Both teachers and students scored 93.69% in the extremely practical category on the two practicality examinations, according to the results. The outcomes of the students' practical experience test earned an average score of 92.71%, including the very practical category. These results demonstrate that the Google Sites e-module is very practical and feasible to be applied in learning, and that students are interested in using it. This finding indicates that the Google Sites-based e-module is highly feasible for use in classroom learning. Moreover, it reflects students' interest in using the module and their ease in understanding the material. This was supported by student feedback stating that *"the e-module is interesting and makes learning easier."*

Similarly, the teacher provided positive feedback, noting that the e-module was well-structured, clearly presented, and easy for students to understand throughout the learning process. This is in line with research that found e-modules built on Google Sites scored 97%,respectively, and are classified as very practical (Hardianti & Alyani, 2023). Table 9 displays the outcomes of the practicality exam for both teachers and students.

Table 9. Achievement of Teacher and Student Practicallity Test

Indicator	Score (%)	Description
Teacher Practicality	94.68	Very Practical
Student Practicality	92.71	Very Practical

This trial phase used two VII classes at Junior High School in Malang. With a total of 46 students, Class VII B was the experimental group, whereas Class VII A was the control group. The trial lasted for five lesson hours. This sampling technique uses a nonprobability sampling type of total sampling. PBL-based Google Sites e-module media was used for teaching conventional media and a lecture style were employed in the experimental class, whereas the control group received normal instruction.

Both the experimental and control classes received pretest and posttest scores in this study. The experimental class had an average pretest score of 28.52, which improved to 76.96 in the posttest. But the control class pretest value was at an average of 27.35 and in the posttest, the value was at an average of 52.09. The posttest findings showed that the control class scored 52.09 on average, while the experimental class scored 76.96. Figure 1 displays the outcomes of the average value acquisition.

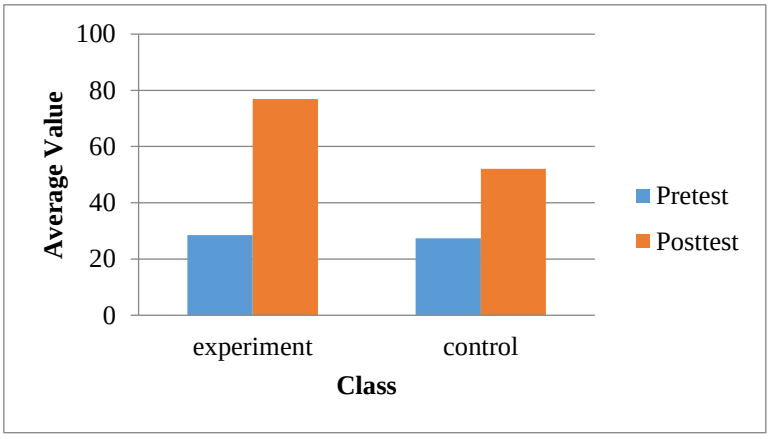


Figure 1. Comparison of pretest and posttest averages

The results of the Shapiro-Wilk normality test indicated that the significance values for the pretest and posttest of both the experimental and control classes were greater than 0.05 (0.462, 0.161, 0.106, and 0.888, respectively). These findings confirm that the data meet the assumption of normality. Table 9 displays the findings of the Shapiro-Wilk Test, also known as the Normality Test. According to (Oktaviani and Notobroto (2014), data is said to be normally distributed if the significance value in the normality test exceeds 0.05. Therefore, all of these data meet normal assumptions and can be further analyzed with a paired sample T-test. As stated by Sugiyono (2017), stating that parametric statistics are used if the data for each research variable to be analyzed is normally distributed. This research is strengthened by the statement that parametric data has assumptions regarding population characteristics and is usually assumed to be normally distributed (L. Cohen et al., 2007).

Table 10. Normality Test Results (Shapiro-Wilk Test)

	df	Sig.
Experimental Class Pretest	22	.462
Experimental Class Posttest	22	.161
Control Class Pretest	22	.106
Control Class Posttest	22	.888

The following test, known as the homogeneity test, determines whether or not the variances of several populations are the same. One of the prerequisites for independent sample t-test analysis is this test. By comparing the two variances, the two-variance similarity test aims to determine whether the data distribution is homogeneous. Only when the data being examined has a normal distribution can this test be performed. Making sure that the differences that show up in parametric statistical tests are, in fact, significant is another benefit of using the homogeneity test (Usmadi, 2020). The significant value (Sig.) based on the mean of 0.260>0.05

indicates that the post-test variables of the control and experimental classes are known to be same or homogenous. The significance value (Sig.) Based on Mean in the pretest results is 0.054 > 0.05, indicating that the pretest variables in the experimental and control classes are homogeneous or not significantly different. Table 11 presents the findings of the homogeneity test.

Table 11. Homogeneity Test Results

Test of Homogeneity of Variances			
Variabel	df1	df2	Sig.
Critical Thinking (Based on Mean) -Posttest	1	44	.260
Critical Thinking (Based on Mean)-Pretest	1	44	.054

Additionally, the study hypothesis was validated using a t-test for independent samples. Kim (2015), explains that the independent t-test can be used to compare findings between groups in posttest conditions. An independent samples t-test can be used to ascertain whether two sets of unpaired or independent samples differ significantly from one another (Sugiyono, 2017). Cohen et al. (2007) stated that When comparing the means of two independent groups, the Independent Samples t-test is utilized. In the book, this test is applied to analyze differences in how students receive guidance and support. The Sig. (2-tailed) value of 0.000 < 0.05 indicates a significant difference in the average critical thinking skills between students who utilize the PBL-based e-module on Google Sites and those who rely on traditional media or the lecture technique, according to the independent sample t-test. However, the experimental and control classes' pretest results showed a sig. (2-tailed) value of 0.773>0.05 according to the independent sample t-test, suggesting that there is either no significant difference or that the results are equivalent. Table 12 displays the findings of the independent sample t-test.

Table 12. Independent Sample t-test

Data	Sig. (2-tailed)
Pretest	P = 0,773
Posttest	P < 0,001

Based on these results, it can be said that students' critical thinking abilities when learning about the respiratory system were much enhanced by using the PBL-based e-module on Google Sites. The N-Gain test was also used to evaluate the effectiveness of the PBL-based Google Sites e-module in the learning process. Table 13 displays the results of the total N-Gain test

Table 13. Overall N-Gain

Data	N	Mean	Std.Deviasion
Experiment	23	0.67	25.65853
Control	23	0.34	30.54007

According to the experimental class's Group Statistics output table, the Mean NGain Percent value is 0.67. The usage of PBL-based Google web-based e-modules in the experimental class is found to be moderately effective in enhancing students' critical thinking abilities, based on the category table of interpretation of the efficacy of the N-Gain value (%).Furthermore, the Mean N-Gain_Percent value for the control class is 0.34. The application of traditional methods (in the control class) is found to be somewhat helpful in enhancing students' critical thinking skills, based on the category table of interpretation of the N-Gain value (%) (Hake, 1999).

Based on the posttest scores, the effect size was calculated using Cohen's d, resulting in a value of 1.21, which is categorized as a large effect (Cohen, 1988). This indicates that the

PBL-based Google Sites e-module had a substantial impact on improving students' critical thinking skills compared to conventional methods

Additionally, each indicator's N-Gain test was performed to gauge how well the Google Sites e-module taught. Considering the findings of the analysis, for critical thinking indications, the average N-Gain score is 0.67, which is categorized as moderate. The N-Gain test results for each indication are provided in Table 14.

Tabel 14. Improvement of each indicator

Indicator	N-Gain (Experiment)	Criteria	N-Gain (Control)	Criteria
Elementary Clarification	0.64	Medium	0.38	Medium
Strategies and tactics	0.55	Medium	0.39	Medium
Basic support	0.79	High	0.24	Low
Advance Clarification	0.64	Medium	0.20	Low
Inference	0.78	High	0.48	Medium

The average proportion of critical thinking indicators was compared between the pretest and posttest findings for the experimental and control groups. The critical thinking indicators applied refer to Ennis' (1985) critical thinking indicators, which include elementary clarification, strategies and tactics, basic support, advanced clarification, and inference. The comparison of the average percentage of each indicator is presented in Figures 2.

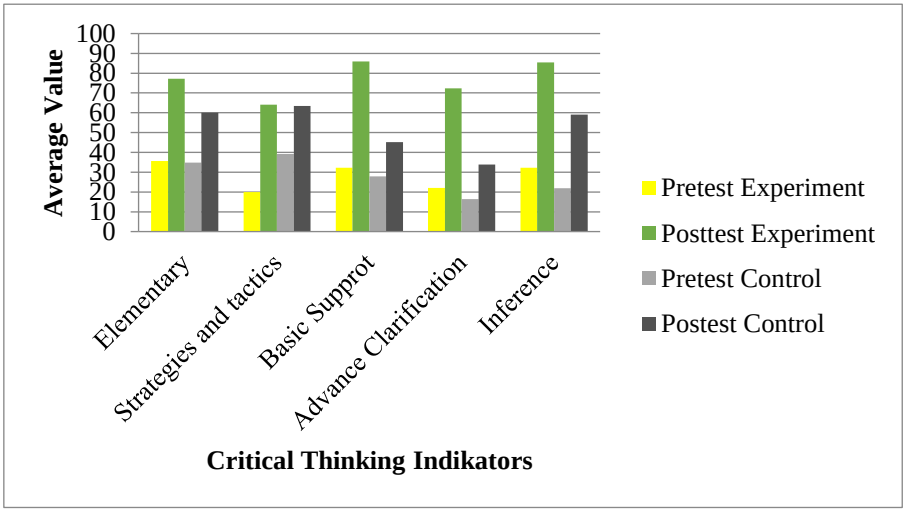


Figure 2. Comparison of the average critical thinking indicators

First indikators is elementary clarification, this essential explanation has to do with a person's capacity to recognize and create queries as well as critically evaluate arguments. In this indicator, it is required of pupils to be able to recognize or create questions, analyze arguments, and ask and answer clarification questions (Ennis, 1985). Critical thinking skills in basic clarification act as a foundation before entering the next stage they require instruction to deepen their critical thinking abilities (Kumala et al., 2022). The average score for the elementary clarification indicator in the experimental class was 35.65 on the pretest, but it increased to 77.13 on the posttest. In contrast, the average score for the control group was 34.48 on the pretest and increased to 60 on the posttest. The results of the N-Gain test indicate that the experimental class received a percentage of 0.64, falling into the moderate group, whereas the control class received a percentage of 0.38, likewise falling into the moderate category.

The activities designed in the e-module and applied in this experimental class can encourage students to identify and formulate questions and analyze arguments fundamentally so that the elementary clarification indicator in this e-module is fulfilled or there is an increase with an N-Gain of 0.64 medium category. Activities to increase the elementary clarification

indicator in the experimental class were trained in the discussion of activities 1 and 2 in stage 1. The activities include each student listening to news about respiratory system problems, and then formulating questions for further study. Furthermore, at the stage of analyzing arguments and answering statements, students are asked to express initial opinions individually about the problems of the respiratory system based on the knowledge they already have. By the research, basic clarification is related to the process of identifying the core of the problem, while important support is related to the ability to recognize and evaluate relevant reasons in dealing with real problems (Kumala et al., 2022).

The increase in critical thinking skills on elementary clarification indicators in the control class was in the moderate category (N-Gain 0.38). This is because students still get learning through textbooks that contain explanations of respiratory system material and simple problems. Although it does not involve in-depth exploration as in the e-module, this conventional learning still allows students to understand basic information that contributes to the improvement of this indicator, although there is an increase in scores, the increase is not as great as that in the experimental class, because students in the control class memorize more material without developing deeper critical thinking.

The second indicator is strategies and tacticsStrategies and tactics refer to one's ability to develop and apply appropriate strategies and tactics. In this indicator, students are expected to identify suitable strategies and engage with others (Ennis, 1985). The experimental class's pretest results showed that the strategies and tactics indicator had an average score of 19.16. Following the posttest, the average score increased to 64.09. In contrast, the pretest average score for the control group was 39.16, and after the posttest, it increased to 63.47. The N-Gain test findings showed that the experimental class earned a percentage of 0.55 which was placed in the moderate group. In contrast, the control group received a 0.39 percentile, falling into the medium range.

The strategies and tactics indicator in the experimental class was trained by students discussing and determining strategies or investigative actions to solve respiratory system problems with the group, then looking for valid sources of information regarding respiratory health problems. According to study by Syafruddin and Pujiastuti (2020), this is consistent with the idea that indications of strategies and tactics are considered good if students are guided to answer problems based on the knowledge they have so that they can find solutions independently. Thus, students' strategic and tactical abilities include skills in solving problems using their own chosen approaches and applying various alternative solutions based on appropriate concepts.

The control class, although the N Gain was 0.39 in the strategies and tactics indicator, the increase in the indicator was limited. This is because students only followed the steps in the textbook, such as reading the text, answering the questions. They were not given the opportunity to design their own strategies in solving problems. As a result, their strategy skills only developed superficially, and the N Gain remained in the medium category.

The third indicator is basic support. Basic support is a person's ability to support their arguments with a strong foundation, including by critically evaluating information sources and observation reports, whereas in this indicator students are expected to consider the reliability of sources and understand and evaluate observation reports (Ennis, 1985). The experimental class's pretest results showed that the basic support indicator's average score was 32.17. The average score increased to 85.83 following the posttest. In contrast, the pretest average score for the control group was 27.82, and after the posttest, it increased to 45.21. The experimental class received a percentage of 0.79, which was in the high group, according to the findings of the N-Gain test. In contrast, the control group received a 0.24 percent, falling into the bottom range.

In the basic support indicator, students are trained to analyze. In activity one, students analyze the organs of the respiratory system by using Augmented Reality (AR) Innerbody

Anatomy - Respiratory System, and in activity 2 analysis by considering prior knowledge and considering the reliability of information sources. In addition, students also do a simple lung model practicum with balloons and collect information obtained in activity 1, and in activity 2 by analyzing cases about the respiratory system. According to studies by Laeni et al (2022), claiming that in the fundamental abilities development stage (basic support), students are guided to collect and process data. They are also trained to conduct experiments independently to obtain information and use procedures that are appropriate to the object being investigated.

In the control class, the teaching materials were not adequate enough in an effort to improve students' critical thinking skills on the indicator, where the N Gain was only 0.24 (low) because the textbook did not provide activities that required students to provide evidence for their answers, they only memorized definitions and answers without practicing supporting arguments logically.

Advanced clarification is a person's ability to analyze concepts define them well, and assess definitions from various perspectives (Ennis, 1985). According to the experimental class pretest findings, the score was 22 on the advance clarification indicator. On the experimental class posttest, the score increased to 72.39. In the control class, the pretest value on this indicator gets an average value of 16.39, and in the post-test, it gets a value of 33.91. The experimental class's N-Gain Test results show a percentage of 0.64, placing them in the medium group, while the control class's findings show a percentage of 0.20, placing them in the low category. This advanced clarification critical thinking indicator is trained by students discussing and compiling definitions related to learning the respiratory system, then evaluating the definitions made as well as assessing the advantages and disadvantages of definitions from a public health and environmental perspective. According to Astuti et al (2018), training in advanced clarification skills involves the process of collecting and classifying information based on certain criteria and selecting answers that match these criteria. This ability is developed at the proof stage, where students are guided to find evidence and provide more in-depth explanations related to the material studied. Therefore, at this stage students are trained to explain the concepts they have obtained (Laeni et al., 2022).

The teaching materials are not adequate in efforts to improve students' critical thinking skills on this indicator in the control class, where the N Gain is only 0.20 (low) because the textbook does not provide space for reflection or evaluation of the learning process, so that students are not trained to prepare further clarifications.

The inference is concluding the information obtained and ensuring that the conclusions are supported by evidence (Ennis, 1985). According to the experimental class's pretest findings, the inference indicator's average score was 32.17. After the posttest, this score increased to an average of 85.35. In comparison, The average pretest score for the control group was 21.91 which rose to 59.13 after the posttest. According to the N-Gain test findings, the experimental class received a percentage of 0.78, falling into the high range. In contrast, the control group received a 0.48, falling into the moderate range. In the inference indicator, students are trained to analyze and evaluate the impact of poor air quality and cigarette smoke on respiratory health and draw conclusions about the symptoms that appear and preventive measures to protect respiratory health. This is to the research of (Laeni et al., 2022), at the concluding stage students are trained to develop the ability to draw conclusions based on relevant and logical considerations. In addition, according to Nopiyadi (2022), students are also guided to draw conclusions based on the results of the discussion, where the conclusions are recorded on the discussion sheet provided by the teacher. They are also trained to conclude with clear and correct statements when presenting data. The increase in critical thinking skills on the inference indicator in the control class was in the moderate category (N-Gain 0.48). This is because students are still trained to summarize the material, but without context or real data, so the conclusions are less critical.

Modules on Google Sites produced the greatest N-Gain score in basic support indicator with a score of 0.79 which is classified as a high criterion. This result indicates that the PBL-based learning approach with the e-module effectively trains students in analyzing the respiratory system through AR Innerbody Anatomy, considering prior knowledge and the reliability of sources, as well as conducting a simple lung model experiment and case analysis. This outcome is consistent with Prastyo and Dimas (2023) research, which outlines that students must evaluate the reliability of the information sources they use, make observations, and weigh the findings of their observations when making decisions as part of the basic support indication. As a result, this method offers a more thorough educational experience, which raises the N-Gain score above other metrics. Furthermore, according to other research, critical thinking entails having the capacity to collect data, evaluate it, reach fact-based judgments, and make wise decisions (Aisyah et al., 2025).

The lowest N-Gain score was in the strategy and tactic indicator with a score of 0.55 in the moderate category. Students still struggle to figure out the correct steps to answer the questions when working on pretest questions; while some students showed improvement in the posttest when they were able to figure out the correct action to answer the questions, some students still lacked confidence in their comprehension of the material, and as a result, their answers were still incomplete. These findings are consistent with research that shows that students who struggle to figure out how to solve a problem are more likely to struggle to provide the right answer (Aisyah et al., 2025). Furthermore, other studies also indicate that critical thinking skills need to be continuously taught along with feedback and improvements to students' critical thinking outcomes (Supriyati et al., 2018).

The study results indicated an improvement in all indicators of students' critical thinking skills. This enhancement was due to the use of a Google Sites-based e-module with the PBL learning model, which effectively supported the development of students' critical thinking abilities. When comparing the experimental class, which used the PBL-based Google Sites e-module, to the control class, which applied the lecture method, the improvement from the pretest to the posttest was significantly greater in the experimental class than in the control class. At first, the two classes' average pretest results were within a nearly identical range. The efficiency of the created e-module was demonstrated by the effectiveness test findings, which revealed that the experimental class's N-Gain was much higher than that of the control group after learning.

The ADDIE model, which is fully implemented, is the model used in this development research, according to the description above. By administering a pretest at the start and a posttest at the end of two classes—the control and experimental classes—this study also passes the efficacy test, which employs a quasi-experimental design of the non-equivalent control group design type. The results indicate that the PBL-based Google Students' critical thinking abilities can be effectively improved by using Google Sites' e-module. Another benefit of this media is that it might assist pupils develop their critical thinking abilities, being flexible and easy to access, providing structured and interesting learning, and supporting 21st-century learning. This e-module is only limited to the material of the human respiratory system using a problem-based learning model and critical thinking skills are measured by referring to the indicators (Ennis, 1985).

One of the limitations in implementing this e-module is the limited learning time in class. However, the advantage of this e-module lies in its flexible and self-paced nature, so that students can access materials, videos, and exercises independently through Google Sites outside of class hours. This feature allows learning to take place continuously, both synchronously in class and asynchronously outside of class, especially in environments with busy learning schedules.

In addition to its advantages, this e-module also has several implementation challenges, especially in rural areas that have limited internet access or devices. Because Google Sites-

based modules require an internet connection to optimally access interactive content, students in areas that do not have adequate signals or devices have the potential to experience obstacles. In addition, potential barriers to digital literacy also need to be considered, especially for students who are not used to accessing digital learning media independently. This is in accordance with research which states that the digital divide is clearly visible, where schools in urban areas have better technological infrastructure and higher access to digital devices compared to schools in rural and remote areas (Subroto et al., 2023).

The study by Syahibudin et al. (2024) shows that limited signal in rural schools such as in Talang Tengah Village significantly hampers e-learning web access, so that group learning solutions are an important alternative. Setiawati et al. (2025) added that the success of digitizing learning in remote areas is highly dependent on contextual solutions such as lightweight mobile applications and smartphone-based educational videos. Therefore, as a strategy, the implementation of learning in this e-module is designed in groups, where only one device can be used by representatives of each group. This strategy minimizes the need for devices per individual and still supports student collaboration in completing PBL-based activities. This approach is quite effective in schools with limited technological facilities

CONCLUSION

Based on the research findings, a PBL-based Google Sites e-module on respiratory system material was successfully developed using the ADDIE model. The module was validated by experts and judged to be feasible, valid, and well-designed for classroom implementation. Field trials with teachers and students demonstrated that the module was highly practical, with an average practicality score of 93.69%. In terms of effectiveness, the e-module improved students' critical thinking skills, as evidenced by an N-Gain score of 0.67 (moderate category) and a Cohen's d effect size of 1.21 (large category). These results confirm that the PBL-based Google Sites e-module is a valid, practical, and effective tool for science learning, particularly for the topic of the respiratory system.

RECOMMENDATION

Science teachers are advised to use this PBL-based e-module in respiratory system learning, especially in the implementation of the Independent Curriculum. This e-module is flexible and can be accessed independently by students both in class and outside of class hours. Because it is equipped with guidelines and activity steps, this module can be used without special training. In schools with limited devices, the module can be used by group representatives to maintain collaboration. Further research is recommended to test the effectiveness of this module on other science materials or different levels of education with a large sample, in order to see the scalability and consistency of the results.

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Conflict of Interest Statement
Authors state no conflict of interest.

Data Availability
The data that support the findings of this study are available on request from the corresponding author [AMS]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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