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Development of e-modul based on three-dimensional thinking graph to improve critical reasoning of junior high school students

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Abstract: The process of strengthening character education in Indonesia is encapsulated in the initiative to enhance the *Profil Pelajar Pancasila*, with critical reasoning being one of its key dimensions. In the context of science education, critical reasoning involves engaging students in the development and testing of hypotheses. This study aims to evaluate the validity, practicality, and effectiveness of an e-module designed based on three-dimensional thinking graphs, intended to enhance critical reasoning among junior high school students in science learning. The research employs the ADDIE development model, with data collected through observation, interviews, tests (pretest and posttest), validation sheets, student response questionnaires, and implementation observation sheets. Results indicate that the e-module is highly valid, with a 93% validation score from experts, practical according to both observers (93%) and student responses (84.4%), and moderately effective, with an effectiveness score of 0.62. These findings suggest that the three-dimensional thinking graph-based e-module is a suitable tool for improving critical reasoning in the science learning process.

Keywords: critical reasoning; e-module; three-dimensional thinking graph

1. Introduction

Education plays a crucial role in shaping the personality and intelligence of children. The ongoing effort to strengthen character education in Indonesia is embodied in the project to enhance the *Profil Pelajar Pancasila*. This initiative provides students with opportunities to explore significant themes or issues, such as climate change, anti-radicalism, mental health, culture, entrepreneurship, technology, and democratic life. Through this exploration, students are empowered to actively engage with and address these challenges in a manner that aligns with their learning levels and individual needs. (Satria et al., 2022). The *Profil Pelajar Pancasila* comprises six dimensions: (1) faith, piety to God Almighty, and noble character; (2) independence; (3) mutual cooperation; (4) global diversity; (5) critical reasoning; and (6) creativity. Among these dimensions, critical reasoning stands out as a crucial element that requires intentional development in students. (Kemendikbudristek, 2022). The successful implementation of this profile is expected to be achieved both effectively and efficiently (Kahfi, 2022).

Critical reasoning, one of the dimensions in the *Profil Pelajar Pancasila*, is a complex process that involves the integration of data acceptance, mastery, analysis, and evaluation. It requires students to consider both qualitative and quantitative aspects and to make informed decisions based on the results of their evaluations (Muhibbin and Fathoni, 2021). According to Ernawati and Rahmawati (2022), the ability to reason critically, which remains underdeveloped in schools, is essential for students as they navigate and solve problems in their family, school, and community environments. It is crucial to teach, apply, and develop this skill to ensure that students approach challenges thoughtfully and skillfully. A common issue in student reasoning is the lack of logical connections between premises and conclusions, often resulting from the use of ambiguous or mixed language, which leads to misunderstandings and inaccuracies (Hayati & Setiawan, 2022). Indicators

of critical reasoning include the ability to obtain and process information and ideas, analyze and evaluate reasoning, and reflect on one's thoughts and thought processes (Kemendikbudristek, 2022).

Critical scientific reasoning is a key 21st-century skill, particularly within the context of science education. This skill is essential for preparing students to adapt to and succeed in the demands of today's globalized world (Yulianti and Zhafirah, 2020). Natural Science is a discipline that examines phenomena based on facts, principles, concepts, and laws that have been rigorously tested through the scientific method (Purwanti et al., 2019). Furthermore, science encompasses a process that integrates factual, procedural, and metacognitive knowledge, all of which are grounded in the scientific method. The concept of science is expanding to include various dimensions, such as scientific concepts, processes, values, attitudes, and the application of scientific principles in everyday life (Wisudawati and Sulistyowati, 2014). Examples of science applications in everyday life include the use of simple machines, such as pulleys, levers, and wheels. These principles are widely applied in various daily activities to enhance efficiency and conserve energy.

In response to these challenges, the development of e-modules has been proposed as an alternative solution. Creating e-modules aims to enhance the effectiveness of the learning process, thereby improving the teacher's role and enabling students to engage in independent learning both in school and at home (Munawaroh et al., 2020). Electronic modules (e-modules) are media designed in electronic format that leverage technological advancements to integrate various components, including text, images, graphics, music, animation, and video (Artiniasih et al., 2019). Module components consist of an introduction, content, activity sheets, and evaluation (Cheva and Zainul, 2019). The interactive e-module presentation focuses on the core content of the material while aligning with the learning objectives to be achieved. The incorporation of video, audio, and animation serves to reduce the reliance on verbal elements typical of traditional printed modules (Kurniawan and Kuswandi, 2021).

The development of this e-module is supported by a Three-Dimensional Thinking Graph (3DTG), designed to enhance the critical reasoning skills of junior high school students in science education. The 3DTG serves as a learning framework that enables students to integrate visual representations, problem information, subject knowledge, and hypothesis and reasoning processes when exploring a problem. It consists of three components: the concept map, the data table, and the reasoning map (Chen et al., 2018). This approach can enhance students' scientific reasoning and critical reasoning skills (Chen et al., 2021). Thus, the researcher aims to develop an e-module based on the Three-Dimensional Thinking Graph to enhance critical reasoning among junior high school students in science education.

2. Materials and Methods

This research employs a development research approach, commonly referred to as R&D (Research and Development). The ADDIE development model guides this research, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. The purpose of this research method is to create products and assess their quality. The product developed is an e-module based on the Three-Dimensional Thinking Graph, aimed at improving the critical reasoning skills of junior high school students in science education. The implementation took place at State junior high school 1 Tempeh, specifically in class VIII C during the odd semester of the 2023-2024 academic year. The selection of this school was based on several criteria. First, the school had not previously implemented an e-module utilizing a three-dimensional thinking graph in its learning activities. Additionally, the use of electronic media in teaching, particularly in science lessons, was minimal.

Data collection techniques included school observations to maximize the effectiveness of the e-module development. Interviews were conducted with science teachers and eighth-grade students to gather insights related to the teaching and learning process, as well as the methods and media used in the classroom. Documentation was

collected in the form of photos, notes, and other materials to provide evidence of classroom activities. Pre-tests and post-tests, formatted as essay questions, were administered to evaluate student engagement and the impact of the e-modules. Additionally, observation sheets were utilized to assess the practicality of implementing the e-module during the learning process. Questionnaires, including validation and student response forms, were also employed. The validation questionnaires aimed to gather feedback and recommendations from validators for product improvement, while the student response questionnaires measured student reactions to the e-module based on the Three-Dimensional Thinking Graphs. The data analysis phase will proceed as follows.

a. Validity Analysis

The validity of the Three-Dimensional Thinking Graph-based e-module is assessed using a specific formula (Formula 1), with the criteria for the validated results presented in Table 1.

$$V = \frac{E_x}{E_{xi}} \; x \; 100 \; \% \tag{1}$$

Table 1. Criteria for Validity Level

Validation Criteria	Category
80% < V ≤ 100%	Highly Valid
60% < V ≤ 80%	Valid
40% < V ≤ 60%	Less Valid
V ≤ 40%	Not Valid

(Kurniasi dan Arsisari, 2020)

b. Practicality Analysis

The practicality analysis of the Three-Dimensional Thinking Graph-based e-module is evaluated using a specific formula (Formula 2), with the criteria presented in Table 2.

$$P = \frac{f}{n} \; x \; 100 \; \% \tag{2}$$

Table 2. Criteria for Practicality Level

Practicality Criteria	Category
81% ≤ P ≤ 100%	Practical
61% ≤ P ≤ 80%	Practical Enough
41% ≤ P ≤ 60%	Less Practical
P ≤ 40%	Not Practical

(Nurhusain dan Hadi, 2021)

c.Effectiveness Analysis

The effectiveness analysis utilized the critical reasoning pretest and posttest scores, along with student response questionnaires.

1. An analysis of critical reasoning ability using N-gain (Formula 3) with the results obtained can be seen in the criteria shown in Table 3.

$$N - gain\ (g) = \frac{posttest\ score - pretest\ score}{100 - pretest\ score} \tag{3}$$

Table 3. Criteria for Effectiveness Level

N-gain	Category
N-gain > 0.7	High
0.3 ≤ *N-gain* ≤ 0.7	Medium
N-gain < 0.3	Low

(Hake, 1998)

2. Analysis of student response questionnaires with the results obtained (Formula 4) can be seen in the criteria shown in Table 4.

$$Precentage\ of\ student\ response = \frac{\Sigma\ number\ of\ questionnaire\ answers}{\Sigma\ maximum\ number\ of\ questionnaire\ answers} \text{ x } 100\% \quad (4)$$

Table 4. Student Response Criteria

Category Practicality Criteria	Category
82% ≤ P ≤ 100%	Very good
62% ≤ P ≤ 81%	Good
44% ≤ P ≤ 62%	Less good
P ≤ 43%	Not good

(Purnianto et al., 2022)

3. Results

The research conducted employs a development research model that results in an electronically presented module, referred to as an e-module. This study utilizes the ADDIE development model, which encompasses several stages: analysis, design, development, implementation, and evaluation. The primary objective of this development research is to produce valid, practical, and effective e-module products.

The analysis stage commenced with observations at State junior high school 1 Tempeh, aimed at gathering information regarding the teaching and learning processes at the school. The analysis revealed insights into learning outcomes, competencies, and objectives, with Class VIII implementing the Merdeka Curriculum to foster the *Profil Pelajar Pancasila*. The teaching materials currently in use consist solely of printed books provided by the Ministry of Education and Culture. An analysis of the students indicated that Class VIII C exhibits diverse characteristics, with some students demonstrating low abilities while others show high capabilities, influenced by the material and teaching methods employed by the instructor.

The design stage focuses on developing the e-module based on a Three-Dimensional Thinking Graph, using "*Pesawat Sederhana*" as the study material. The design aligns with the teaching module, *Alur Tujuan Pembelajaran* (ATP), and critical reasoning skills assessments based on the Three-Dimensional Thinking Graph. The e-module is created using Canva, converted into JPG or PNG format, and subsequently uploaded to LiveWorksheet. The Three-Dimensional Thinking Graph-based e-module consists of 43 pages, including a cover, preface, table of contents, introduction, content, summary, competency test, and bibliography. It features worksheets aligned with the Three-Dimensional Thinking Graph and critical reasoning indicators. Figure 1 and Figure 2 illustrate the cover and contents of the e-module.

After the e-module is accurately arranged and deemed complete according to the material, it is uploaded to LiveWorksheet. The next step involves publishing the e-module and obtaining an access link (https://www.liveworksheets.com/w/id/ilmu-pengetahuan-alam-ipa/7277455), which is then converted into a barcode. This barcode is placed on the second front cover of the e-module, allowing students to scan it for easy access, as illustrated in Figure 3.

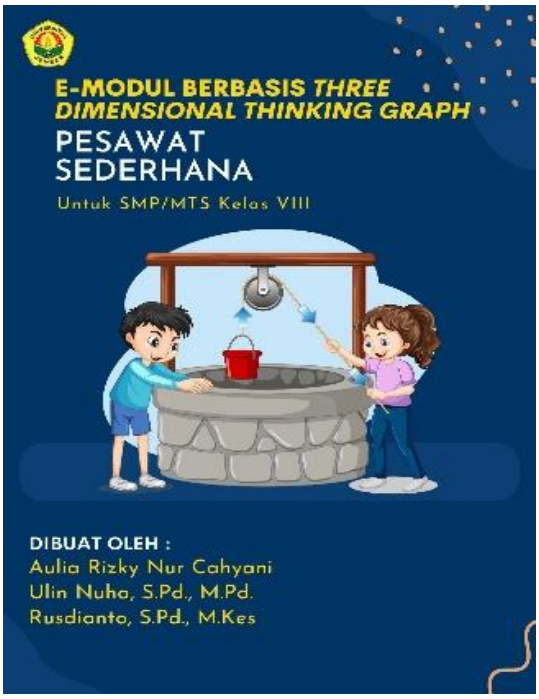

Figure 1. Cover of e-module

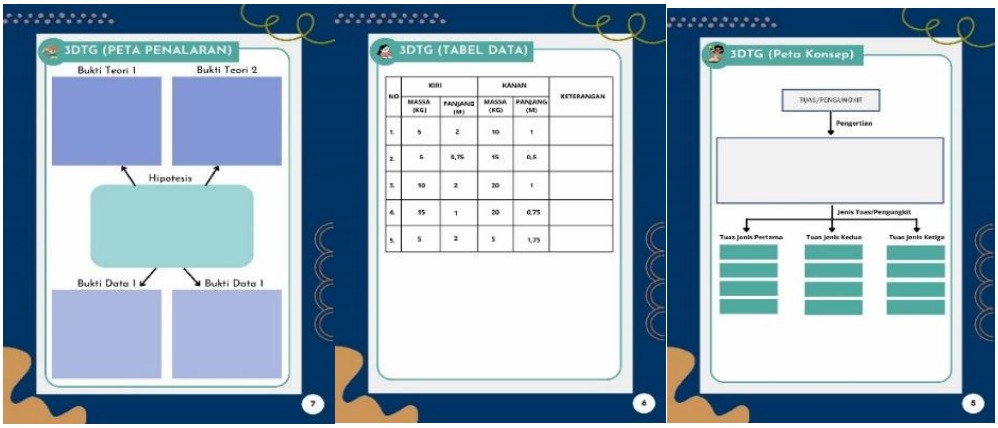

Figure 2. Contents of e-module based on three dimensiona thinking graph

Figure 3. Second cover and e-module barcode

The development stage focuses on developing the e-module design that has been designed and then validated by experts. Validation is conducted to determine the feasibility of the e-modules for use in the learning process. It also serves to review and assess the prepared questions, which support the development research. Following this, the validators—comprising two teachers and one lecturer—will evaluate the e-module's feasibility and provide feedback on its effectiveness. The results of the validation for the e-module based on Three-Dimensional Thinking Graph-based, aimed at enhancing critical reasoning in junior high school science education, are presented in Table 5.

Table 5. Three dimensional thinking graph based e-module validity results

Assessment Aspect	Score Interval			Percentage (%)	Category
	Validator 1	Validator 2	Validator 3		
Aspects of the three dimensional thinking graph approach to improve critical reasoning	0.96	0.92	0.875	92	Highly Valid
Languange aspect	0.95	0.95	0.90	93	Highly Valid
Content aspect	0.95	0.85	0.90	90	Highly Valid
Practicality aspect	1.00	1.00	0.92	97	Highly Valid
Average score	**0.96**	**0.93**	**0.90**	**93**	**Highly Valid**

Based on the validation results from 3 validators, the average obtained in all aspects is 93%, and the assessment category obtained is very valid. It can be concluded from these results that the e-module based on a three-dimensional thinking graph to improve critical reasoning can be used in the learning process. This stage has also been adjusted with several revisions based on validator suggestions.

The implementation stage in conducting product tests of e-modules based on a three-dimensional thinking graph with VIII C class students included as many as 30 students at State junior high school 1 Tempeh. Practicality analysis assessment data was collected using an implementation observation sheet conducted by three observers. The learning implementation observer sheet is used to assess and observe each step in the implementation of learning. The following are the results of the implementation of learning that has been filled in by observers, as shown in Table 6.

Based on these results, the implementation of learning using Three-Dimensional Thinking Graph-based e-modules achieved an average percentage of 93% across all meetings, categorizing it as practical. The implementation results for various aspects of the learning process, as assessed by three observers over four meetings, indicate that the e-modules are effectively integrated into the teaching module. This demonstrates that the use of e-modules based on the Three-Dimensional Thinking Graph can be considered both practical and implementable.

The evaluation stage is conducted at the end of the study to assess the improvement in students' critical reasoning skills and their responses following the use of the developed e-module products. This stage serves as a key measure for analyzing the effectiveness of the Three-Dimensional Thinking Graph-based e-modules in enhancing critical reasoning. Validated test questions were administered to Class VIII C students at State junior high school 1 Tempeh to evaluate the effectiveness of the e-modules. The assessment involved two tests: a pretest and a posttest. The results of the pretest and posttest for the critical reasoning skills of Class VIII C students can be seen in Table 7.

Table 6. Results of the implementation of an e-module based on a three dimensional thinking graph

Aspects obsecved	Learning implementation score			Percentage (%)	Category
	Observer1	Observer2	Observer3		
Students can access the e-module application and utilize it effectively.	0.88	1.00	0.88	92	Practical
Students can develop proficiency in using the Three-Dimensional Thinking Graph-based e-modules to understand the material related to *Pesawat Sederhana*.	0.94	0.88	0.81	88	Practical
Students can effectively obtain and process information and ideas	0.75	1.00	1.00	92	Practical
Students can reflect on their thoughts and cognitive processes	1.00	1.00	1.00	100	Practical
Students can analyze and evaluate various forms of reasoning	0.75	1.00	1.00	92	Practical
Average score	**0.86**	**0.98**	**0.94**	**93**	**Practical**

Table 7. Results of the effectiveness of students critical reasoning ability

Component	Score		N-gain	Category
	Pretest	Posttest		
Total of students	30	30	0.62	Medium
Average	49,53	80.82		

The assessment of students' critical reasoning revealed an average pre-test score of 49.53 and a post-test score of 80.82. The results of the pre-test and post-test were analyzed using the N-gain test to evaluate the improvement in students' critical reasoning. The final N-gain value was 0.62, categorized as medium. This value indicates a significant increase in students' critical reasoning skills following the use of e-modules based on three-dimensional thinking graphs.

Students' response to the e-module based on a three-dimensional thinking graph for improving students' critical reasoning is an analysis of the effectiveness of the e-module. Student response questionnaires were given to 30 students in class VIII C at State junior high school 1 Tempeh. The results of the data analysis of student responses to e-modules based on a three-dimensional thinking graph can be seen in Table 8.

Table 8. Results of the effectiveness of students response questionnaires

Aspects observed	Percentage (%)	Category
Interest	86.7	Very good
Theory	81.8	Good
Languange	84,6	Very good
Average student response	**84.4**	**Very good**

Based on the response questionnaire that has been shown, it was found that the average student response result is 84.4%, which is categorized as very good. All aspects of interest, material, and language can make students understand and be motivated to carry out the teaching and learning process in simple aircraft material using e-modules

based on a three-dimensional thinking graph. This can show that the use of e-modules based on a three-dimensional thinking graph is fairly good and effective in improving critical reasoning.

4. Discussion

The research began with observations to analyze the curriculum, students, classroom environment, and technology at State junior high school 1 Tempeh, which were gathered through interviews with science teachers and school observations. The findings revealed that the school implements two curricula: Curriculum 13 for grade XI and the Merdeka Curriculum for grades VII and VIII. Students often report feeling bored, as the teaching methods are predominantly lecture-based and conventional. The teaching materials consist solely of printed textbooks. In terms of character education, the school provides opportunities for students to develop various skills, including critical reasoning, which is crucial for helping students effectively address problems and engage in a more meaningful learning process (Ernawati and Rahmawati, 2022). However, teachers have not conducted activities or training aimed at enhancing students' critical reasoning abilities. This is evident in students' responses, which are generally brief and lack justification, particularly when answering essay questions related to science, such as the application of simple machines in everyday life. The use of technology at the school is also limited. Students primarily rely on devices like cellphones and laptops for tasks such as typing and searching for information online. Overall, the integration of technology into the learning process is minimal and infrequent.

Based on the results of interviews, analyses conducted at State junior high school 1 Tempeh, and a review of previous literature, the researchers developed e-modules based on three-dimensional thinking graphs to enhance students' critical reasoning in science education. According to Chen et al. (2021), the three-dimensional thinking graph (3DTG) can be effectively integrated into science learning through the use of concept maps, data tables, and reasoning maps, which serve as foundational elements of the e-modules aimed at improving critical reasoning. Enhancing students' critical reasoning, a key component of the Pancasila learner profile in the Merdeka Curriculum, can be achieved through this approach. Such modules enable students to cultivate a mindset that encourages openness to new evidence, systematic and scientific thinking, fact-based conclusions, and effective problem-solving, thereby fostering logical and critical thinking skills.

The e-module based on the three-dimensional thinking graph is a product developed through development research. For an electronic module (e-module) to be considered suitable for use, it must meet three key criteria: validity, practicality, and effectiveness. This aligns with the perspective of Sabrina et al. (2021), who stated that the feasibility assessment of a developed product is divided into three key aspects: validity, practicality, and effectiveness. The e-module includes content such as instructional material, practice questions designed to enhance critical reasoning, group assignments based on the three-dimensional thinking graph, and competency tests. These components are accessible online to students, facilitating their learning and assessment.

Based on the assessment of three validators, it can be concluded that the e-module based on the three-dimensional thinking graph is valid. Both the content and material suitability, evaluated from various aspects, have been deemed valid. This aligns with the theory of Asri and Dwiningsih (2022) which suggests that media validity can be assessed through content validity and construct validity. Content validity determines the relevance of learning media to the learning materials, focusing on spatial and visual suitability for enhancing student intelligence, as well as material alignment. Construct validity refers to the theoretical foundation underlying the development of the instrument. Content and construct validity are evaluated across several aspects, including the three-dimensional thinking graph approach to improving critical reasoning, language, content, and practicality.

The validation of content in the three-dimensional thinking graph-based e-module is demonstrated through the aspects of the three-dimensional thinking graph approach and

the content of the e-module, both of which have met the standards with results of 92% and 90%, respectively, categorizing them as very valid. The practicality aspect included in the construct validation received a final score of 97%, categorizing it as very valid. This high rating is reflected in the e-module's engaging design and user-friendly interface, which ensures that students remain interested and find it practical to follow the learning process. The design and media display of the e-module based on the three-dimensional thinking graph effectively support an engaging and accessible learning experience for students. The final result of the e-module validation, based on the three-dimensional thinking graph, was 93%, categorizing it as highly valid. In accordance with the opinion of Asri and Dwiningsih (2022), a developed media can be considered valid if the validator's assessment yields a percentage above 60%. Thus, the e-module can be regarded as valid for use.

An e-module is considered effective and suitable for learning if it meets specific criteria, including being self-instructional, self-contained, stand-alone, adaptive, and user-friendly. These features ensure that the e-module functions effectively as a teaching tool, enabling students to engage in self-directed learning and assess their understanding through the exercises provided in the module (Dona & Syafriani, 2022). The e-module includes instructional materials, three-dimensional thinking graph exercises, and related questions to help students grasp the concept of simple machines. These materials cover topics such as levers, axles, pulleys, and inclined planes, followed by exercises based on the three-dimensional thinking graph to enhance students' critical reasoning skills. According to Chen et al. (2018), the concept of a three-dimensional thinking graph, which trains students in solving problems using conceptual scientific reasoning, is designed to enhance students' abilities. This approach is reflected in the e-module's instructions, which incorporate three key components of the three-dimensional thinking graph: concept maps, data tables, and reasoning maps, particularly in group assignments. The e-module's design aligns with critical reasoning indicators, including obtaining and processing information and ideas, analyzing and evaluating reasoning, as well as reflecting on thoughts and thinking processes. These elements are embedded in individual assignments, which serve to train students in improving their critical reasoning skills.

The final score for the use of e-modules based on a three-dimensional thinking graph is 93%, categorizing it as practical. This indicates that the implementation of learning using these e-modules is practical. The practicality assessment is based on the analysis of various aspects observed throughout the learning process, including the learning steps, the use of e-module teaching materials, and the evaluation. According to Mustami et al. (2017), the practicality of a learning tool is considered satisfactory or good if the developed tool can be effectively applied according to expert assessments and can be successfully implemented in real classroom settings during the learning process.

The effectiveness of the e-modules based on a three-dimensional thinking graph in improving critical reasoning was evaluated through pretests, posttests, and student response questionnaires. The pretest had an average score of 49.53, while the posttest score increased to 80.82. The pretest and posttest results were analyzed using the N-gain test to measure the improvement in students' critical reasoning. The final N-gain value was 0.62, which is categorized as moderate. This indicates a significant improvement in students' critical reasoning skills after using the e-modules based on a three-dimensional thinking graph. Based on the N-gain results, the use of this e-module can be considered effective, as it led to an increase in students' critical reasoning abilities. This is in line with the opinion of Mutmainnah et al. (2021). The effectiveness value obtained can be used to determine the success rate of using media in the learning process.

The student response questionnaire for the use of the e-module was administered to 30 students from class VIII C at State junior high school 1 Tempeh. The analysis of student responses to the e-modules based on a three-dimensional thinking graph yielded a result of 84.4%, categorizing it as very good. The e-module effectively motivated students and helped them understand the material on simple machines. The use of an attractive design,

clear instructions for operation, and practice questions contributed to enhancing students' critical reasoning skills. These features made it easier for students to engage with and benefit from the e-modules. In accordance with the opinion of Puspitasari et al. (2021), an e-module with an attractive design and easy-to-understand features can enhance student motivation and engagement in the learning process. This, in turn, positively influences learning outcomes and contributes to improved student performance.

5. Conclusions

The research results indicate that the e-modules based on the Three-Dimensional Thinking Graph are classified as highly valid, practical, and moderately effective for use with the material on simple aircraft. The e-module achieved a validity score of 93%, while the practicality assessment based on the implementation sheet also rated at 93%. Additionally, the practicality as measured by the student response questionnaire was 84.4%, and the effectiveness in assessing critical reasoning skills was determined to be 0.63. The findings show a notable increase in critical reasoning scores as evidenced by both the e-module assessments and the administered tests. Overall, the implementation of the Three-Dimensional Thinking Graph-based e-modules to enhance critical reasoning has met the necessary criteria and can be effectively integrated into the science learning process for junior high school students

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