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Enhancing Critical Thinking Skills in Junior High School Students through the RADEC Learning Model on Vibration Material

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Abstract: In the rapidly evolving contemporary era, countries globally, including Indonesia, are compelled to adapt, with the Partnership for 21st Century Skills (P21) highlighting the crucial role of Critical Thinking, Creativity, Collaboration, and Communication (the 4Cs) for student success in the 21st century, yet traditional teacher-led learning often overlooks critical thinking skill development, contributing to low proficiency levels evident in assessments like the Programme for International Student Assessment (PISA). This study aims to describe the implementation of the Read, Answer, Discuss, Explain, and Create (RADEC) model on critical thinking skills in vibrations. The research design employed is descriptive through a one-group pretest-posttest design. The subjects of this study were 34 students in class VIII-A at SMP Negeri 54 Surabaya during the even semester of the academic year 2023/2024. Data collection techniques involved observation, tests, and questionnaires. Research instruments included learning implementation observation sheets, critical thinking skills tests, and student response questionnaires. The test results were analyzed using N-Gain and paired t-tests. The study's findings revealed that implementing the RADEC learning model on vibrations met the criteria very well, with a mode fully implemented. The student's critical thinking skills improved by an N-Gain analysis result of 0.38 and a paired t-test result of 0.000. The students also highly accepted the learning process using the RADEC model in the topic of vibrations, with 86% of statements strongly agreeing. Based on the description above, implementing the RADEC model can enhance students' critical thinking skills regarding vibrations.

Keywords: Critical thinking; RADEC model; Vibrations.

Introduction

Significant changes in all aspects of life characterize the 21st century. Consequently, every country, including Indonesia, must adapt to the demands of the times. The US-based Partnership for 21st Century Skills (P21) identifies four skills students need to thrive in the 21st century: Critical Thinking, Creativity, Collaboration, and Communication, commonly called the 4Cs [1]. Additionally, Thornhill-Miller [2] introduces essential skills and knowledge for the 21st century, emphasizing learning and innovation skills, including creative thinking and problem-solving, communication and collaboration, and the ability to create and innovate. These skills are fundamental for individuals to succeed in the 21st century.

Critical thinking is critical in 21st-century education [3]. The National Council for Excellence defines critical thinking as the application of conceptualizing, analyzing, synthesizing, and evaluating information gained through experience, application, and reflection [4]. Developing and introducing critical thinking skills is essential for everyone [5]. Critical thinking enables individuals to determine objectives, recognize relationships between things, and consider decisions to ascertain truth and education [6], [7]. Components of critical thinking include analytical skills, deductive reasoning, evaluation, and problem-solving [8]. Critical thinking skills have five indicators: providing simple explanations, building basic skills, inference, giving further explanations, and strategizing or planning [9].

Teacher-led learning practices often neglect the enhancement of critical thinking skills. This lack of awareness is reflected in the Programme for International Student Assessment (PISA) results. According to the 2022 PISA results, the global average standard score in science is 485, while Indonesia's average score is 383, ranking 67th out of 81 countries [10]. Despite an improvement in ranking from 71st in 2018 to 67th in 2022, Indonesia's science score dropped by 13 points from 2018, trailing the global average by 102 points, indicating that Indonesia remains at a low proficiency level. Hardika [11] states that PISA questions require high-order thinking skills that can foster students' critical thinking abilities. Additionally, Karim & Normaya [12] report that junior high school students in Indonesia generally exhibit low critical thinking skills.

Preliminary studies conducted at SMP Negeri 54 Surabaya support these findings, indicating low critical thinking skills among students, particularly in inference (12%), advanced clarifications (14%), and strategizing or planning (12%). However, indicators such as providing simple explanations and building basic skills were relatively high, with percentages of 86% and 82%, respectively. This is because science education is not student-centred, resulting in a lack of understanding of learned concepts. These findings demonstrate that students' critical thinking skills are low in specific indicators such as inference, advanced clarifications, and strategizing or planning, which is why this study focuses on these indicators.

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The main cause of low critical thinking skills is the continued use of traditional teacher-centred learning methods. In practice, many teachers dominate learning activities using conventional techniques, which do not promote high-order thinking skills in students. Teacher dominance during learning makes students mere objects of education. Research by [13] concludes that teachers teach students to memorize rather than implement investigative, innovative learning. Similarly, Sopandi [14] notes that teachers do not understand the syntax of innovative learning models, resulting in the continued use of conventional methods. Classroom activities are dominated by assignments and memorization, leading to low student participation in critical thinking skills [15]. Much of the memorized material remains in short-term memory, so students' thinking skills are limited to recalling, stating, or referencing without processing [16].

The use of innovative learning models is still minimal among teachers. Research by Sopandi [14] shows that only 10% of primary and secondary school teachers in West Java can write the syntax of frequently used innovative learning models. Other teachers either struggle to understand or write the syntax or mistakenly believe they are implementing innovative learning models when they are not. This indicates that innovative learning models have not been maximally implemented in Indonesia.

The Read, Answer, Discuss, Explain, and Create (RADEC) model is an innovative learning model that can enhance students' critical thinking skills. According to [14], the RADEC model can develop critical thinking skills by searching for information sources or other learning materials. The RADEC model facilitates the generation of various ideas from each student, fostering critical thinking. In the Read stage, knowledge is acquired and becomes the foundation for building critical thinking. The Create stage further develops critical thinking [17]. Pratama [18] also recognizes the RADEC model as a recent innovation aligned with the characteristics of Indonesian education, offering significant breakthroughs in the learning process to achieve competencies relevant to 21st-century demands. The RADEC model, first introduced by Sopandi [19] at an international conference in Kuala Lumpur, Malaysia, aligns with the syntax Read, Answer, Discuss, Explain, and Create. Its syntax is easily remembered by primary and secondary education teachers [14], making it suitable as an alternative innovative learning model in Indonesia.

Several studies also show that the RADEC model positively impacts student learning outcomes [20]. Sukmawati [21] demonstrates that the RADEC model can improve learning outcomes. Jumanto [22] found that the RADEC model enhances creative thinking skills. Pratiwi [23] shows that the RADEC model effectively develops students' conceptual abilities. Furthermore, Pratama [18] indicates that the RADEC model strengthens critical thinking skills. However, none of these studies have specifically investigated the RADEC model to improve junior high school students' critical thinking skills in science subjects, particularly at SMP Negeri 54 Surabaya.

The selection of vibration material to train critical thinking skills aligns with Nurhayati [24], who states that material closely related to daily life can support students' critical thinking. Vibration can be applied in daily life contexts such as technology, music, or even the human body. Students are expected to solve everyday problems related to the equations and applications of the vibration concept through learning vibration material. Therefore, efforts to train critical thinking skills in solving these problems are necessary [25].

Research on enhancing the critical thinking skills of junior high school students through the RADEC learning model on vibration material is crucial and relevant in the current educational context. By addressing the challenges in science education and the development of critical thinking skills, this research has the potential to provide broad positive impacts for students, teachers, and the education system as a whole. Therefore, this study aims to describe the enhancement of students' critical thinking skills by implementing the RADEC model. Based on this background, the researcher intends to conduct a study titled "Enhancing Critical Thinking in Junior High School Students through the RADEC Learning Model on Vibration Material."

Research Methods

The type of research used in this study is pre-experimental research with a One Group Pretest-Posttest Design. The study begins with administering a pretest to assess the initial critical thinking skills, followed by implementing the RADEC learning model as the treatment. It concludes with a posttest to measure the improvement in critical thinking skills. This research was applied to class VIII-A in the even semester of the 2023/2024 school year at Junior High School 54 Surabaya with 34 students. The sample was obtained using a purposive sampling technique.

This study utilizes observation techniques, tests, and questionnaires for data collection. The research instruments include learning observation sheets, critical thinking test sheets (pretest and posttest), and student response questionnaires. Data on the implementation of learning is analyzed as ordinal data using a Guttman scale where "Yes" corresponds to a score of 1 and "No" corresponds to a score of 0. The overall student responses can be analyzed. Each indicator will then be assessed based on this scale. The analysis involves determining the mode, or the most frequently occurring value, for each item, phase, and overall.

The critical thinking test results are analyzed using pretest and posttest scores. This involves conducting a n-gain, normality test, and a paired sample t-test.

$$\langle gain \rangle \frac{\langle Posttest \rangle - \langle Pretest \rangle}{\langle Maximum\ Score \rangle - \langle Pretest \rangle}$$

[26]

Table 1. Interpret of Normalized Gain

Interval	Category
(<g>)>0.7	High
0.7≥(g)≥0.3	Moderate
(<g>) <0.3	Low

[26]

The normality test, performed using the Shapiro-Wilk method in SPSS, determines if the data is normally distributed (significance value greater than 0.05) or not (significance value less than or equal to 0.05). The paired t-

test assesses the difference between pretest and posttest results. If the significance value is more than 0.05, there is no significant difference. In contrast, a value less than 0.05 indicates a significant difference in the average scores of the critical thinking tests before and after the intervention.

Data from student response questionnaires are presented in a graph, as they are ordinal data measured on a Likert scale with four categories: strongly agree (4), agree (3), slightly agree (2), and disagree (1). The analysis involves identifying each statement item's mode, or the most frequently occurring value. Subsequently, the overall mode is determined from these individual modes.

Results and Discussion

The research data obtained include implementing the learning model, the results of students' critical thinking skills tests, and student responses.

Implementation of the Learning Model

Implementing the RADEC model in science learning is supported by Student Worksheets (LKPD), which have been designed and validated. These worksheets contain guidelines that assist students in enhancing science literacy by integrating science literacy indicators into each stage of the RADEC model. The learning using the RADEC model was conducted over two sessions in class 8A.

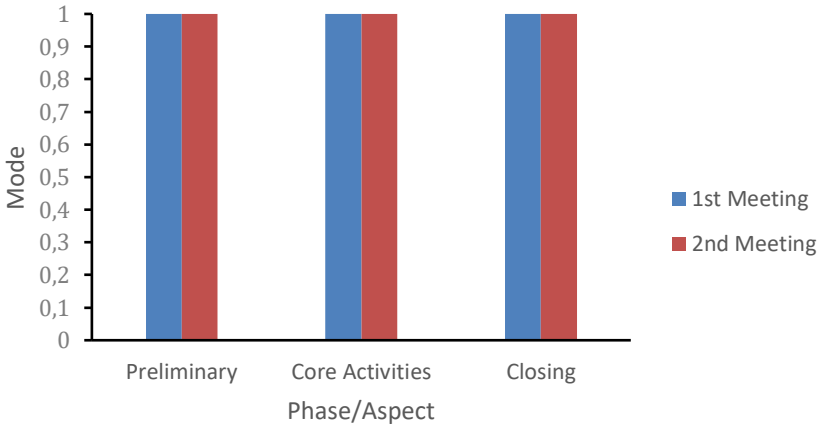

Figure 1. Result of Learning Implementation

In the first session, the introductory aspect was executed very well. The teacher successfully conditioned the class, motivated the students, conducted a preliminary assessment, communicated the learning objectives, explained the importance of learning outcomes, provided an outline of the learning activities, and consistently checked the students' prior knowledge, as evidenced by the maximum scores given by all observers. This indicates that preparation and introduction of the material are crucial for building a strong foundation for an effective learning process [27]. In the core stages, namely, Read, Answer, Discuss, and Explain, the teacher also successfully carried out these activities. The teacher instructed students to independently read books related to vibrations and various references at home and to prepare pre-learning questions to be filled out at home.

Additionally, the teacher formed groups with varying levels of ability, guided the students in group discussions, and asked them to write down their group discussions' results. This supports collaborative learning, where interaction among students can enhance their understanding and social skills [28]. However, the Create stage was not conducted in the first session as planned to be carried out after all the materials in one topic had been read, discussed, and presented classically in the second session [17]. In the closing activities, the teacher successfully helped the students summarize the learning outcomes and conduct an assessment of the learning results, achieving maximum scores from the observers. However, the teacher needs to improve the reflection on the learning process with the students and provide follow-up assignments after the learning activities, as these two aspects are essential to ensure that students understand the material taught and can apply it in a broader context [29].

In the second session, the implementation of the learning activities continued to show positive results. In the introductory aspect, the teacher again conditioned the class, motivated the students, conducted a preliminary assessment, communicated the learning objectives, explained the importance of learning outcomes, provided an outline of the learning activities, and checked the students' prior knowledge effectively. Consistency in the introductory stage demonstrates the importance of routine in creating a conducive learning environment [30]. All activities from the Read to the Create stages were implemented in the core stages. The teacher instructed students to independently read books related to vibrations and various references at home, prepare pre-learning questions to be filled out at home, form groups, guide group discussions, ask students to write down the results of their discussion and request students to present their group's answers in front of the class and provide responses and reinforcement, showing an improvement from the previous session. In the Create stage, the teacher guided the students in conducting experiments related to vibrations and then instructed them to create a product based on the results of the vibration experiments. The Create stage allows students to apply the knowledge they have gained in a tangible form [31]. In the closing activities, the teacher

showed improvement in facilitating students to summarize the learning outcomes, reflect on the learning process with the students, and provide follow-up assignments after the learning activities. This is important to ensure the continuity of learning and the student's understanding of the taught material [32]. The assessment of learning outcomes was also consistently carried out, which is a crucial component in evaluating the effectiveness of learning and providing feedback to students. Overall, the implementation of the RADEC model in the two sessions showed positive results in executing the learning activities.

Critical Thinking Skill

The results of the N-gain analysis, which categorized the improvement of students' science literacy skills, can be accumulated and presented in Figure 2.

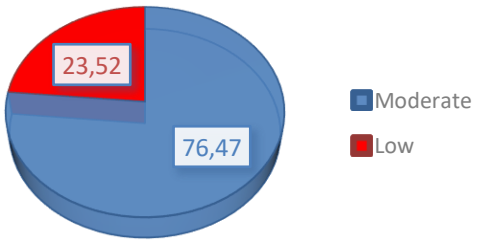

Figure 2. Diagram of Scientific Literacy Skills Improvement

Figure 2 shows that the most significant increase in students' critical thinking skills falls within the medium category, with a percentage of 76.47%. This is followed by the low category with a percentage of 23.52% and the high category with a percentage of 0%. The data was then tested for normality using the Shapiro-Wilk test through the SPSS application as a prerequisite. The data can proceed with the dependent sample t-test if it is normally distributed. The purpose of the dependent sample t-test is to determine whether there is a significant effect on student's critical thinking skills after the implementation of the RADEC model in science learning on the topic of vibrations. The data used for the normality test includes the pretest and posttest data.

Table 2. Result of Normality Test Shapiro-Wilk

	Statistic	df	Sig,
Pretest	0.943	34	0.074
Posttest	0.969	34	0.429

The results of the normality test using Shapiro-Wilk, as shown in Table 3, indicate that the pretest scores are normally distributed with a significance value of 0.074, greater than 0.05 (0.074 > 0.05). Similarly, the post-test scores are normally distributed with a significance value of 0.492, greater than 0.05 (0.492 > 0.05). Based on the Shapiro-Wilk normality test results, it can be concluded that the pretest and posttest scores are normally distributed, allowing for parametric statistical tests. The hypothesis testing for the normally distributed pretest and posttest scores is then conducted using the parametric statistical test, specifically the dependent sample t-test, with the assistance of SPSS version 20.0. The results of the paired sample t-test are presented in Table 3.

Table 3. Result of Paired Sample t-test

	Mean	t	df	Sig,
Pretest-Posttest	-22.206	-14,289	33	0.000

Based on Table 3, the paired t-test results show a significance level of < 0.05, which means that Ho is rejected and Ha is accepted. This decision indicates a significant difference in improving students' critical thinking skills before and after the learning process with the RADEC model. Table 3 also shows a negative t-value, indicating that the average pretest score for critical thinking skills is lower than the average posttest score. The negative t-value ($t_{computed}$) can be interpreted positively, indicating an improvement. When the t-computed value is compared to the t_{table} value of 1.554, with t-computed > t_{table}, the same decision is reached: Ho is rejected, and Ha is accepted. This demonstrates a significant difference in the improvement of students' critical thinking skills before and after the implementation of the RADEC model. This finding is consistent with the research by Satria & Sopandi [33], which demonstrated that the RADEC learning model can enhance critical thinking skills. This is attributed to the cognitive apprenticeship process during learning with the RADEC model, wherein individuals gradually learn from Read (R) to Create (C) to acquire knowledge through interaction with experts, thereby stimulating their critical thinking skills [34], [35]. Additionally, the RADEC learning model aligns with Vygotsky's constructivist theory in learning [17].

The increase influences the improvement in students' critical thinking skills in the average score for each critical thinking skill indicator. The enhancement of critical thinking skills for each aspect can be observed in the following table.

Table 4. The Results of Improvement for Each Critical Thinking Skill Indicator

Indicator	N-gain	Criteria
Inference	0.17	Low
Advanced Clarifications	0.66	Moderate
Strategy and Tactics	0.31	Moderate

Based on the improvement of each critical thinking skill indicator after learning with the RADEC model, it is found that critical thinking skills in advanced clarifications and strategy and tactics have increased with a medium n-gain category. Meanwhile, the skill of inference has increased with a low n-gain category.

The indicators of critical thinking skills used correspond to Ennis [9], namely advanced clarifications, organizing strategies or tactics, and inference. The first indicator, advanced clarifications, showed an N-gain of 0.66,

categorized as moderate. This skill is crucial in critical thinking because it invclarifying, interpreting, and explaining information in more detail. This result aligns with [36], which indicated that discussion-based and presentation-based learning can enhance students' ability to provide further explanations.

The second indicator, organizing strategies or tactics, showed an N-gain of 0.31, categorized as moderate. This is due to students' developing abilities to plan and implement learning strategies. Students accustomed to more conventional learning approaches need time to adapt to collaborative approaches like the RADEC model. According to Gupta & Ahmad [37], structured learning strategies enhance students' critical thinking skills. This skill is crucial in critical thinking development because it inplanning, organising, and managings.

The third indicator, inference, showed an N-gain of 0.17, categorized as low. This is due to factors such as the lack of independent practice among students in inference. Inference is a critical thinking skill that requires a deep understanding of the provided information and the ability to integrate various ideas into a logical conclusion. According to Ennis [9], this skill is one of the most challenging aspects of critical thinking. Therefore, improving critical thinking skills requires contextual learning, which has been shown to enhance essential abilities of thinking [38]. The stages of the RADEC model, such as group discussions and presentations, should help students develop critical thinking skills [35]. However, there may need to be more emphasis on activities specifically designed to train the skill of inference. According to Nikolaishvili [39], practice in reflective thinking and critical analysis is key to developing critical thinking skills. However, the inference skill showed only a low n-gain, suggesting that inference, w concluding evidence and reasoning, may be more challenging due to its abstract nature and the cognitive load it demands. This result is consistent with other research, such as [40], which highlights that improving inference skills requires explicit instruction, extensive practice, and immediate feedback, elements that might not be fully addressed within the RADEC model's framework.

The improvement in critical thinking skills using the RADEC model is influenced by several factors, namely the cognitive apprenticeship process, collaboration, and social interaction. The RADEC model incorporates these approaches, where students gradually learn from Read (R) to Create (C) to acquire knowledge through interaction with experts, which stimulates their critical thinking skills by allowing them to observe and imitate the essential behaviours of their educators [41]. The stages of the RADEC model facilitate crucial thinking [17]. The first stage in the RADEC learning model is reading, where the teacher instructs students to read textbooks and references related to the concepts to be studied independently at home one week before the lesson begins. The second stage is answering, where students answer pre-learning questions from the teacher based on their reading,practising elementary clarification, initiative, and independence in finding answers. The teacher also classifies the difficulty levels of concepts based on students' answers. The third stage is discussing, where students discuss in groups to agree on answers to the pre-learning questions, with the teacher ensuring that all students are involved, thus fostering critical thinking skills such as primary support and inferencing [33]. In the explaining stage, students present their group's answers to the class, enhancing critical thinking skills in advanced clarification. The teacher is a moderator and presenter to clarify the material and respond to students' opinions, promoting communicative skills and confidence ([43]. The final stage is creating, where students are encouraged to think of creative ideas, approve, realize, and report their product ideas, cultivating creativity and practical application of the concepts studied [17].

The RADEC model encourages collaboration and social interaction through stages such as group discussions and presentations [17]. Social interaction with teachers and peers provides opportunities to discuss ideas, receive feedback, and practice critical thinking skills through constructive dialogue [33].

Students' Respons

The student responses to implementing the RADEC model are presented in Figure 3.

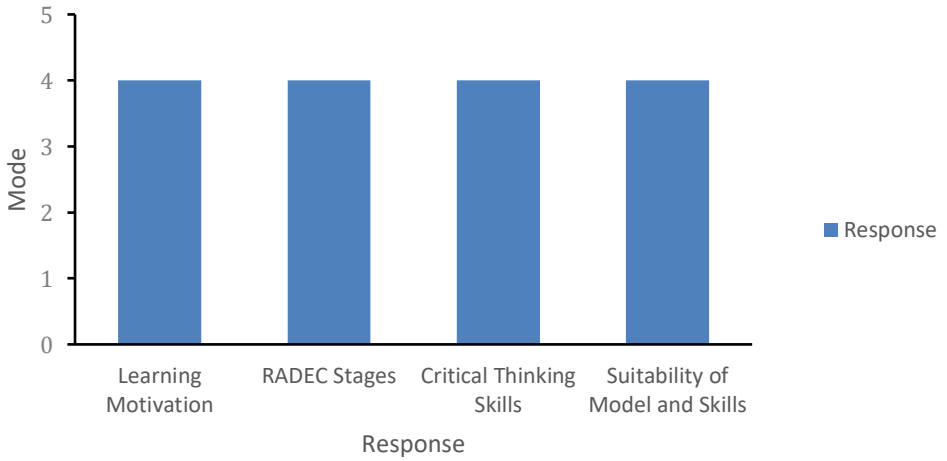

Figure 3. Result of Learning Implementation

Based on Figure 3, the overall student responses have a score of 4, indicating a "strongly agree" criteria. Each indicator also has a mode of 4, indicating "strongly agree" as well. The students' responses to implementing the RADEC model in learning are presented in Figure 3. Overall, the students' responses show a mode score of 4 with the criteria

"strongly agree," indicatinthe students very well received the RADEC modelC model. In the first statement, students stated tpresented phenomenahenomena captured their attention and increased their motivation to study vibrations, with a modcore 4. This suggests that the RADEC appreffectively engages students' interest, consistent with Slavin's [27] findings that engaging learning can enhance student motivation. The second statement indicates that learning with the RADEC model is not boring, which also received a mode score of 4. This aligns with [44], who state that active engagement in learning makes the process more enjoyable and interesting. In the third and fourth statements, students felt more active in lear,ning, and their active role increased during the implementation of the RADEC mowith a mode score of 4. This shows that RADEC is effective in enhancing student engagement, supporting research by Pohan [45], which found that this model can increase learning activity in the classroom. The fifth statement shows that students are not confused when the material on vibrations is presented using the RADEC model, with a mode score of 4. This indicates that the structure and steps in the RADEC model make the material more accessible for students to understand [46]. In the sixth statement, students stated that the lessons taught made them better understand and remember the material, with a mode score 4. Active and collaborative learning can improve understanding and retention of material [47]. Statements seven through ten highlight the benefits of specific stages in RADEC, such as reading, providing questions in the Student Worksheet, and group discussions.

All these statements have a mode score of 4, indicating that these activities make the learning process more structured, assist in learning, and increase students' motivation and understanding. Statements eleven to thirteen also have a mode score of 4, indicating that discussions among friends in groups, presentation activities, and experiments or product creation motivate students to learn and increase their courage to ask questions and provide suggestions. This shows the importance of social interaction and collaboration in learning, which is in line with Vygotsky's theory on the importance of social interaction in learning [34]. Statements fourteen to sixteen highlight improvements in students' abilities to conclude, provide scientific explanations, and strategize and plan after participating in learning with the RADEC model, all with a mode score of 4. The RADEC model can enhance students' critical and analytical thinking skills [33]. Statements seventeen to nineteen affirm that the RADEC model makes it easier for students to understand the material, think critically, express opinions enthusiastically, and gain new experiences and knowledge, all with made score 4. The RADEC model successfully creates a learning environment that supports the development of critical thinking skills and active participation. The final statement shows that the teacher's assessment and feedback can improve students' understanding, with modTeacher feedbackdback is crucial in the learning process to help students identify their strengths and weaknesses and guide them in further learning [48]. Overall, the students' responses indicate that implementing the RADEC model is very effective in increasing the motivation, active participation, understanding, and critical thinking skills of the students.

Conclusion

Based on the data analysis and discussion, it can be robustly concluded that implementing the RADEC (Read, Answer, Discuss, Explain, and Create) learning model was highly influential in enhancing students' critical thinking skills. The mode of implementation scored 1, indicating strong alignment with the instructional module. Post-implementation analysis further substantiated this effectiveness, revealing a significant improvement in critical thinking skills with an N-gain score of 0.38, categorizing it as moderate. This improvement was underscored by paired t-test results showing a notable difference in students' critical thinking skills before and after the learning process. Moreover, student feedback was overwhelmingly positive, with 86% strongly agreeing on the RADEC model's efficacy in fostering critical thinking abilities. These findings collectively highlight the RADEC model as a potent facilitator for enhancing students' critical thinking capabilities in educational settings.

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