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The Effectiveness of a Differentiated Process Teaching Module to Improve Students' Critical Reasoning Skills in the Context of Rational Numbers

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Abstract

This study aims to examine the effectiveness of developing differentiated process learning modules on rational number material in improving students' critical reasoning skills. This study has a novelty in developing learning modules, namely by integrating process differentiation through the ADDIE (Analyze, Design, Development, Implementation, Evaluation) development model. This approach provides hope in adjusting the needs of diverse learners so that it has the potential to be more optimal in achieving learning objectives. The research method used is quantitative, with a one-group pretest-posttest design. The trial was conducted on 24 students at SMP Negeri Satu Atap 1 Kalipucang, Pangandaran Regency, West Java. The research instruments include student and teacher response questionnaires, as well as pretest and posttest tests to measure improvements in critical reasoning skills. The results of the study showed a significant increase in students' critical reasoning skills, with an average pretest score of 21.15 and a posttest score of 77.92. The average N-Gain value of 0.7279 (72.79%) showed a high increase in achievement. In addition, statistical analysis using a paired sample t-test with a p-value of 0.000 and an effect size of 5.831 proved that the differentiated process learning module had a very large impact on improving students' critical reasoning skills. The use of this module is effective because it not only improves learning outcomes but also encourages students to be more active in critical thinking through a more personalized and tailored learning approach. Thus, this learning module can be adopted by other educators as a tool to support more inclusive and effective learning in improving students' high-level thinking skills.

Keywords: teaching modules, differentiated learning, rational numbers, critical reasoning skills, research and development (R&D), ADDIE

INTRODUCTION

The Merdeka Curriculum, introduced by the Ministry of Education, Culture and Technology of Indonesia, aims to foster a flexible and adaptive learning environment tailored to the diverse needs of students. Central to this curriculum is the development of 21st-century competencies, including critical reasoning, creativity, and collaboration,

which are essential for preparing students for future challenges (Kepmendikbudristekdikti, 2022). One of the primary goals of the Merdeka Curriculum is to enhance students' ability to think critically and independently, particularly in subjects including mathematics, in this framework, the development of conceptual understanding and problem-solving skills is fundamental. However, students often struggle with foundational mathematical concepts such as rational numbers, a critical area of learning in the curriculum. The challenge lies not just in procedural knowledge, but in equipping students with the deeper, critical thinking skills necessary to understand and apply these concepts in varied contexts (Yulianasari & Sukiman, 2024).

Rational number concepts are crucial in building students' mathematical fluency, yet studies have shown that many students face difficulties in applying these concepts to real-world situations. For instance, only 56% of students are able to solve rational number story problems correctly, indicating significant gaps in their conceptual understanding and critical reasoning skills (Jayanti et al., 2021). This gap is particularly concerning given the increasing emphasis on critical thinking and problem-solving skills as part of the 21st-century competencies outlined in the Merdeka Curriculum.

One potential solution to addressing this challenge is differentiated instruction. Differentiated learning allows teachers to adapt teaching methods and materials to address the diverse abilities, learning styles, and needs of students (Tomlinson, 2014). This approach is particularly useful in mathematics, in which students often struggle with conceptualizing abstract ideas. For example, using tiered tasks, scaffolding questions, and grouping students by ability can provide more targeted support (Rositawati, 2019). These strategies can directly address the difficulties students face in understanding rational numbers by providing them with tailored learning experiences. However, while differentiated instruction is widely supported, its practical application in teaching rational numbers remains underexplored (Lee & Griffin, 2021).

Existing teaching modules often emphasize procedural fluency, focusing on mathematical rules and operations rather than fostering critical reasoning and problem-solving skills. This oversight highlights a significant gap in the educational resources available to teachers and students, particularly in mathematics education (Putra et al., 2023). To bridge this gap, there is a clear need for teaching modules that not only address procedural fluency but also encourage critical thinking, allowing students to engage deeply with the material.

This research aims to address these gaps by developing and evaluating a differentiated process teaching module specifically for rational numbers. The module integrates visual, auditory, and kinesthetic learning styles to engage students with varying needs, using tiered activities, individualized pacing, and contextualized problem-solving tasks. For example, students at the "emerging" level will work on concrete representations of rational numbers, while "advanced" learners will be tasked with solving abstract problems that involve real-world applications of these concepts. By incorporating these strategies, the module aims to foster critical reasoning and enhance students' problem-solving abilities in alignment with the goals of the Merdeka Curriculum (Fitria, 2024).

This study contributes to the body of educational research by demonstrating how differentiated teaching modules can effectively address learning gaps in mathematics,

particularly in the understanding of rational numbers. The findings will provide valuable insights for educators looking to implement the Merdeka Curriculum in their classrooms and for curriculum developers seeking evidence-based strategies to enhance critical reasoning in mathematics. Furthermore, this research offers a novel contribution by focusing specifically on differentiated instruction for rational numbers, an area where existing research is limited (Lee & Griffin, 2021). Through pretest-posttest evaluations, this research will assess the effectiveness of the module in improving critical reasoning and its alignment with the competencies outlined in the Merdeka Curriculum.

In conclusion, this study highlights the importance of developing educational resources that not only address the procedural aspects of mathematics but also foster the critical reasoning skills required for real-world problem-solving. The research will offer both theoretical and practical contributions to the ongoing development of the Merdeka Curriculum and its implementation in mathematics education, particularly for teaching rational numbers.

METHODS

This study adopts a quantitative approach to measure the improvement in students' critical reasoning skills following the implementation of a differentiated process teaching module developed using the ADDIE model (Analyze, Design, Development, Implementation, Evaluation) (Mega et al., 2022). The ADDIE framework was chosen due to its systematic and iterative nature, ensuring that the teaching module is well-structured, relevant, and effective (Branch, 2009). The research commenced with the Analyze stage, during which a needs analysis was carried out to identify gaps in students' understanding of rational numbers. (Thibodeau, 2023). Observations, teacher interviews, and pretest results were utilized to categorize students into three readiness levels: "needing help" (scores < 50%), "proficient" (50–75%), and "advanced" (> 75%). In the Design stage, learning objectives were formulated, and the module was tailored to accommodate visual, auditory, and kinesthetic learning styles (Cherkasova, 2024). Differentiated tasks within the LKPD (Student Worksheets) were aligned with Bloom’s taxonomy to address varying levels of complexity. During the Development phase, the module was validated by three material experts and two media experts using criteria such as content relevance, language clarity, and question difficulty, achieving validity scores above 90% (Shobab & Wartofsky, 2023).

The Implementation phase involved applying the module to 24 students at SMP Negeri Satu Atap 1 Kalipucang, Pangandaran Regency, West Java (Fakhrurriana, 2023). This small sample size was chosen to allow detailed observation and iterative refinement, considering time and resource constraints (Nurani et al., 2024). The implementation was conducted over two meetings (Ramadhan & Harmayani, 2024). In the first meeting, which lasted two hours, students underwent a pretest to assess initial abilities, followed by grouping based on readiness levels (Sánchez, 2024). Tailored LKPD were distributed: the "needing help" group received basic-level tasks emphasizing conceptual understanding, the "proficient" group worked on intermediate tasks integrating real-life scenarios, and the "advanced" group tackled complex problems requiring higher-order thinking (Fitzpatrick et al., 2024). In the second meeting, lasting two hours, the module

focused on rational number topics such as discounts and taxes, with LKPD adjusted to maintain differentiation based on learning styles and readiness levels (Melka & Jatta, 2022).

The Evaluation stage included the use of critical reasoning tests and questionnaires validated by five experts (Masykur et al., 2024). Validation criteria comprised content relevance, alignment with learning objectives, and usability, resulting in an average validity score of 95%, categorized as "very valid." Data analysis was conducted using SPSS version 26 (Pamio et al., 2024). The paired sample t-test was employed to determine the significance of pretest-posttest differences, supported by normality (Kolmogorov-Smirnov test) and homogeneity (Levene's test) tests to validate the analysis. The N-Gain test measured the magnitude of improvement in critical reasoning skills, while the effect size test assessed the practical significance of the intervention (Chen, 2023). This methodological approach ensures rigorous evaluation of the teaching module's effectiveness in enhancing students' critical reasoning skills.

RESULTS AND DISCUSSION

Results

Following the implementation of the differentiated process teaching module on rational number material (Chimmalgi & Hortsch, 2022), posttest results indicated a significant improvement in students' critical reasoning skills. Figure 1 compares the average pretest and posttest scores, highlighting a marked increase in performance following the module's application (Dawes et al., 2020). Meanwhile, Figure 2 illustrates the percentage of achievement for each critical reasoning indicator seeking information, assessing information, drawing conclusions, and making decisions demonstrating students' progress post-intervention.

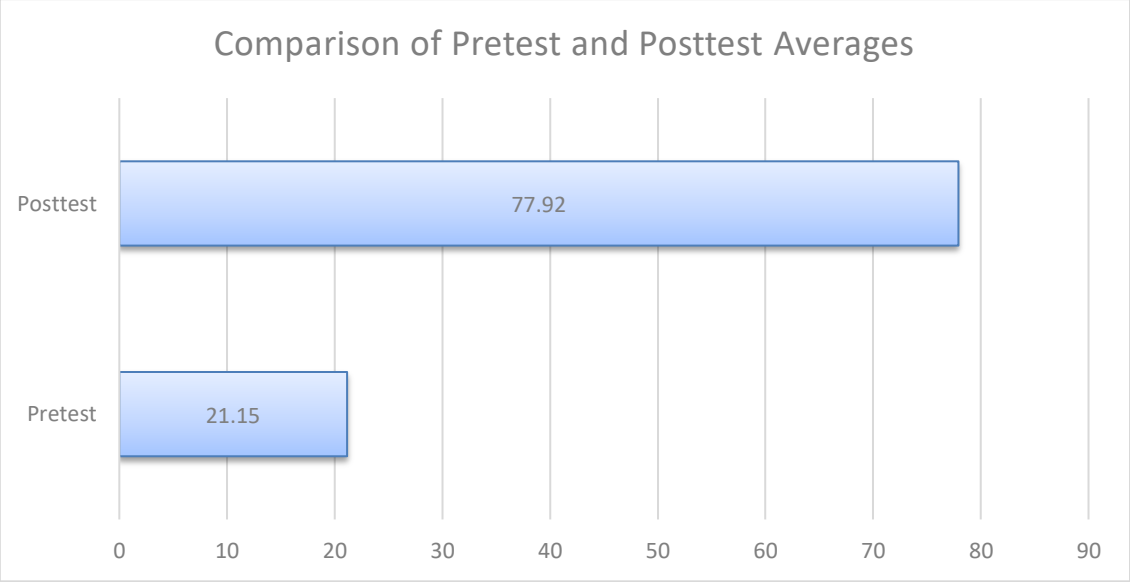

Figure 1 Comparison of Pretest and Posttest Averages

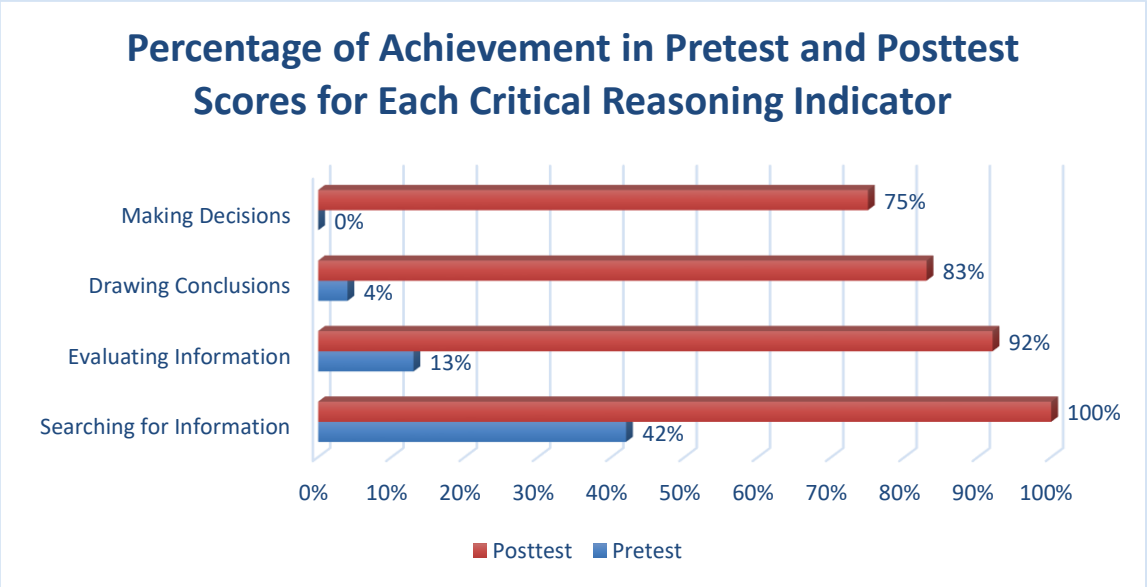

Figure 2 Percentage of *Pretest* and *Posttest Score Achievement* for Each Critical Reasoning Ability Indicator

The results of the study indicated that, on average, the use of the differentiated process teaching module contributed to the improvement of students' critical reasoning skills (Azis & Ayudia, 2024). Before the implementation of the module, the pretest results were still low; only 42% of students were able to search for information, 13% were able to assess information, 4% were able to draw conclusions, and none were able to make decisions (Takahashi & Wakasugi, 2023). The pretest scores ranged from 7.5 to 42.5, with an average of 21.15. After the use of the teaching modul (Maulida et al., 2024), the average achievement in the posttest increased quite significantly; namely, 100% of students were able to search for information, 92% were able to assess information, 83% were able to draw conclusions, and 75% were able to make decisions. The post-test scores ranged from 60 to 95, with an average of 77.92 (Wibowo et al., 2024). The comparison between the pretest and posttest showed a significant increase, indicating the success of the teaching modul in improving students' critical reasoning skills (Mykhailova & Humankova, 2022).

Next, the *N-gain calculation is carried out*, which is shown in Table 1.

Table 1. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain Score	24	0.54	0.93	0.7279	0.09620
N-Gain Percent	24	54.29	92.59	727.891	961.987

Based on descriptive statistical analysis, the average *N-Gain* score is 0.7279 with a standard deviation of 0.09620, indicating high score consistency between 0.54 and 0.93. This result shows good achievement (Sari et al., 2024). Furthermore, prerequisite tests were carried out on the *N-gain value data*, namely normality and homogeneity tests (Pranata, 2024). The normality test with *Shapiro-Wilk* showed that the pretest and posttest

data were normally distributed (p> 0.05), while the homogeneity of variance test with *Levene's Test* showed no significant difference between groups (p> 0.05) (Dwikoranto, 2023). With the fulfilment of the assumptions of normality and homogeneity of variance, the next analysis used a paired sample *t-test* to compare the pretest and posttest averages (Kourki & Tribak, 2021).

Table 2. Paired Differences

Pair	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
1	-5666.667	559.827	114.274	-49.588	23	0.000

Based on the results of the *t-test* in Table 2, the *t* -t-value = -49.588 with degrees of freedom (df) = 23 and p-value = 0.000 is obtained, which is smaller than the significance level of α = 0.05. In addition, the *t* -t-value obtained is smaller than *the t* -t-table (±2.069), which leads to the rejection of the null hypothesis (H_0), which states that there is no difference between the pretest and posttest scores (Fitri et al., 2023). Conversely, sthe alternative hypothesis (H_1), which states that there is a significant difference, is accepted (Amini et al., 2022).

After conducting the difference improvement test, to see the effectiveness of the process differentiated teaching module, an *Effect Size test was conducted* using the following formula:

$$ES = \frac{m_A - m_B}{\sigma}$$

$$ES = \frac{77.92 - 21.15}{9{,}74}$$

$$ES = 5.831295471$$

From the calculations carried out, the *effect size value was obtained* at 5.831295471, which falls into the " *Strong Effect* " criteria (Fitria, 2024). This shows that the use of differentiated process teaching module in learning activities has a very strong influence on improving students' critical reasoning skills (Prastowo & Elvi, 2023). In other words, the implementation of this differentiated process teaching module has proven effective in significantly improving students' critical reasoning skills .

As support for the quantitative data above, the following graph also presents the results of the student response questionnaire (Ruckert et al., 2021), which shows their responses to the use of differentiated process teaching modules in learning rational numbers (Amara et al., 2023).

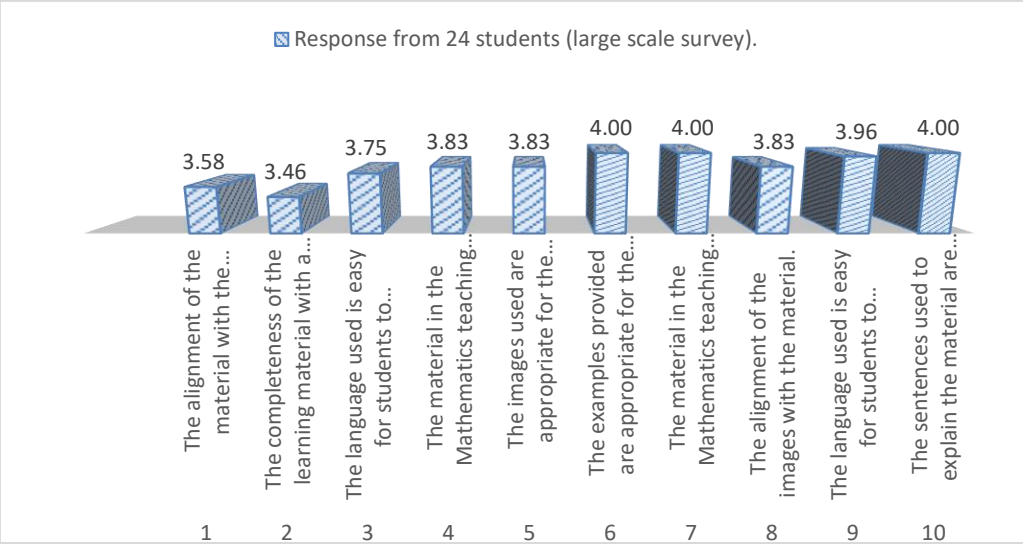

Figure 3. Graph of Average Score of Large Group Student Response Questionnaire

Figure 3 shows the average score of the response questionnaire filled out by 24 students, with a total average score of 3.825, which is included in the "very good" category (Birkness-Gartman et al., 2022). This shows that students' responses to the use of the process-differentiated teaching module are very positive. High scores indicate that students feel that this module is effective and useful in supporting their learning process (Mittal et al., 2024). Subsequently, students engage in posttest tasks designed to assess the quality and effectiveness of the teaching module in enhancing their critical reasoning skills (Hasanah et al., 2023).

The following shows an excerpt from the Differentiated Process Teaching Module that has been developed to improve student's critical reasoning skills , which facilitates three learning styles and three student learning needs to be used in this study:

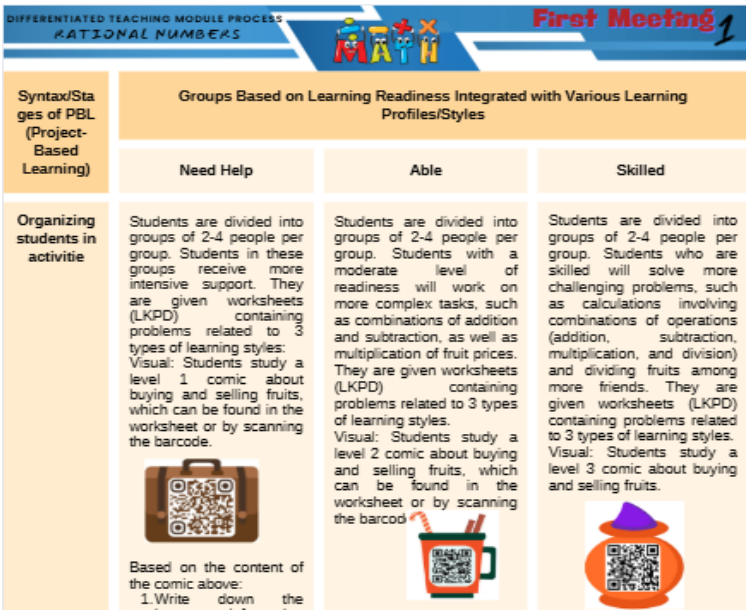

Figure 4. Process of Organizing Students (Visual)

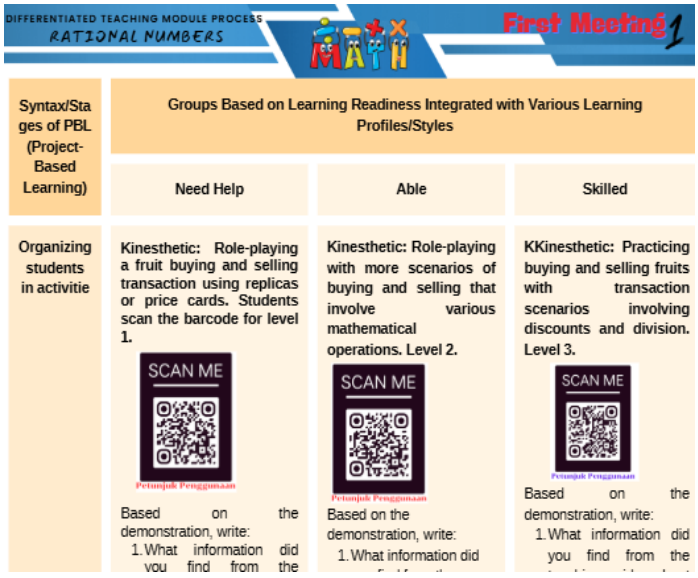

Figure 5. Process of Organizing Students (Kinesthetic)

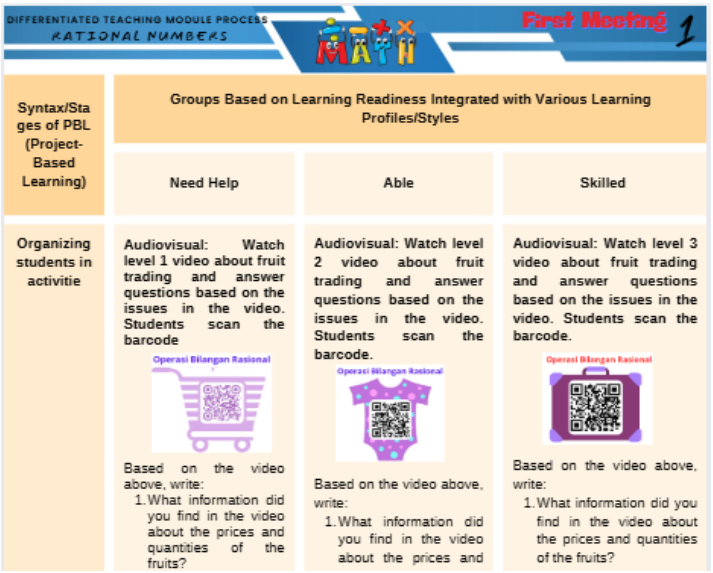

Figure 6. Process of Organizing Students (Audiovisual)

Discussion

Based on exploratory data from research results, a significant increase in students' critical reasoning skills was observed after using the process-differentiated teaching module (Katzman & Sharp, 2022). This improvement addresses existing issues in traditional teaching methods, which often fail to cater to diverse learning styles and do not provide sufficient emphasis on developing higher-order thinking skills. Before implementing the teaching module, students' critical reasoning skills were notably low, especially in evaluating information and making decisions based on analysis (Pearson, 2022). However, after utilizing the teaching module, a marked improvement was evident across all indicators, demonstrating its effectiveness in bridging these gaps.

The increase for each indicator was substantial and supported by the t-test results on N-Gain data, which confirmed a significant improvement in students' critical reasoning

skills after learning with the process-differentiated teaching module (Karlina et al., 2024). This module effectively addresses the deficiencies highlighted in the pretest data by incorporating targeted strategies to enhance critical thinking abilities. For instance, pretest results showed that only 42% of students were able to seek information, 13% could assess information, 4% could draw conclusions, and none were able to make decisions. In contrast, the posttest results demonstrated significant growth, with 100% of students successfully seeking information, 92% assessing it, 83% drawing conclusions, and 75% making decisions. This progression highlights the effectiveness of the teaching module in addressing existing problems in critical reasoning development (Sugebo et al., 2024).

The effect size calculation further reinforced the success of the teaching module, yielding a value of 5.83, categorized as a "Strong Effect" (Cohen, 1988). This substantial effect size demonstrates that the teaching module had a strong influence on improving students' critical reasoning skills, thereby providing a solution to the limitations of traditional instructional methods. Additionally, a student response questionnaire showed an average score of 3.825, categorized as "very good," indicating that students found the module engaging, relevant, and highly effective in enhancing their critical reasoning abilities (Pérez-Pérez, 2021).

Several factors contributed to this success. First, the module was designed to accommodate various learning styles, including visual, auditory, and kinesthetic, which allowed students to engage with content in ways that suited their preferences. This inclusivity not only improved comprehension but also fostered critical reasoning skills (Faiz & Kurniawaty, 2022). Second, an initial assessment of students' learning styles and readiness enabled the adjustment of materials and groupings based on their abilities, ensuring personalized and relevant learning experiences (Sadova & Kalyta, 2021). This approach supported the development of critical reasoning skills, as it aligned with each student's readiness and needs (Fitriani, 2023). Third, the differentiation strategies employed in the module included tiered activities, guiding questions, and cooperative tasks, which encouraged students to engage in higher-order thinking and collaborate effectively. These activities created opportunities for deeper understanding and improved reasoning (Nur et al., 2023). Lastly, the module utilized flexible groupings based on learning readiness and styles, allowing teachers to adjust tasks to suit the needs of each group. This adaptability fostered an optimal environment for the development of critical reasoning skills (Purnawanto, 2023).

The differentiated process teaching module offered several advantages that directly addressed existing gaps in traditional instructional methods. It was designed to be user-friendly, with clear instructions and engaging materials equipped with animations depicting real-life situations, which sparked students' enthusiasm for learning. The module's design encouraged curiosity by posing discovery-based questions that led students toward understanding the concepts of rational numbers (Ray et al., 2022). Additionally, group discussions, role-playing, and the freedom to choose activities aligned with students' interests created a more dynamic and enjoyable learning process (Schmitt et al., 2024). The inclusion of challenging and thought-provoking exercises, aligned with clear indicators for critical reasoning, further enhanced the students' learning experience. The module also offered flexibility through print and digital formats,

accessible via barcodes, providing convenience and preventing monotony (Balz et al., 2022).

In conclusion, the differentiated process teaching module successfully addressed the critical gaps in students' reasoning abilities by offering targeted, inclusive, and engaging instructional strategies. Its strong positive impact, as evidenced by quantitative and qualitative data, underscores its effectiveness in fostering critical reasoning skills (Lukovic & Brierley, 2023). By integrating diverse learning styles, personalized instruction, and interactive content, this module represents a robust solution to the challenges of traditional education, ultimately equipping students with essential reasoning skills for their academic and personal growth.

CONCLUSION

Based on the findings of the research, it can be concluded that the use of the process-differentiated teaching module on rational number material effectively addresses the research problem by significantly improving students' critical reasoning skills. The findings demonstrate that this module provides an effective solution to the diverse learning needs of students while enhancing their understanding of rational number concepts. This research contributes meaningfully to the development of effective teaching modules that align with the principles of differentiated learning. By addressing diverse learning preferences and abilities, the module facilitates a more inclusive educational environment that fosters critical thinking and engagement.

The analysis showed substantial improvements in students' performance, with a marked increase in pretest and post-test scores. The N-Gain value of 0.7279, categorized as high, indicates a significant practical improvement in students' critical reasoning abilities. The effect size of 5.83 underscores the strong impact of the module, signifying that the magnitude of the improvement is not only statistically significant but also educationally meaningful. Additionally, the p-value of 0.000 confirms that the results are highly statistically significant, validating the effectiveness of the module in enhancing critical reasoning skills. Positive student feedback further supports these findings, with an average questionnaire response score of 3.825 falling in the "very good" category. This indicates that students found the module highly beneficial and engaging in their learning process. The module's capacity to meet diverse learning needs, boost motivation, and enhance understanding of rational number material highlights its potential for broader application.

To build on these findings, several recommendations are proposed. First, the process-differentiated teaching module should be explored in other subject areas, such as algebra, geometry, or science, to assess its broader applicability and benefits. Second, to increase student engagement and interactivity, the module should incorporate advanced educational technologies. Suitable elements include interactive animations, augmented reality (AR), and virtual reality (VR)-based applications that can provide immersive learning experiences and foster deeper understanding. Third, conducting studies at different educational levels, such as primary or senior high school, will help validate the module's effectiveness across a broader range of learners and contexts. Fourth, the

module's design and implementation should align with relevant education policies, such as the Merdeka Curriculum, which emphasizes differentiated and student-centered learning approaches. By supporting such policies, the module can contribute to the national agenda for improving education quality and inclusivity.

These steps will not only enhance the module's effectiveness but also extend its relevance and impact in diverse educational settings. By fostering a deeper understanding of rational numbers and critical reasoning skills, this research underscores the importance of differentiated learning strategies in modern education.

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