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Exploring Critical Thinking in Environmental Education: A PBL Approach to Reaction Rate Material at Public Senior High Schools in Indonesia

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Abstract: This study investigates students' critical thinking abilities through a problem-based learning (PBL) approach, focusing on environmental-based reaction rate material. The study was conducted at a Public Senior High School in Jakarta the capital city of Indonesia, it involved 35 students, utilizing a descriptive quantitative method. The assessment tool for critical thinking skills comprised descriptive questions. Analysis of the data revealed percentages for each critical thinking indicator: providing a simple explanation (68.57%), determining the basis for decision-making (56.71%), offering further explanation (56.42%), drawing a conclusion (52.85%), and employing tactics and strategy (46.42%). In conclusion, when exposed to environmental-based reaction rate material through PBL, students' critical thinking skills fall within the category of being sufficiently critical. This study provides valuable insights into the intersection of environmental education and pedagogical approaches.

Keywords: Critical Thinking Skills; Problem-Based Learning (PBL); Environmental Education; Reaction Rate Material; Student Performance

1. Introduction

The rapid evolution of science and technology, particularly within the education sector, underscores the dynamic landscape that demands constant adaptation. Aligned with established graduate competency standards, the primary objective of education is to nurture students' logical reasoning, thinking understanding, and analytical proficiency [1]. Within this framework, chemistry is a pivotal subject that actively contributes to achieving these educational objectives. Notably, critical thinking skills emerge as a linchpin in effective chemistry education. Positioned at a higher cognitive echelon, these skills empower students to excel within the classroom and navigate and surmount challenges that await them in the broader context of their future endeavors.

In the contemporary era, where information is ubiquitously accessible yet not uniformly verified, the role of education has become increasingly pivotal. Beyond imparting subject-specific knowledge, education is critical in equipping students to evaluate and discern the integrity of the information presented [2][3]. As students engage with the complexities of science and technology, the cultivation of critical thinking skills becomes imperative for fostering a generation capable of understanding the intricacies of these fields and questioning, analyzing, and applying their knowledge in varied contexts.

This intersection of education, critical thinking, and the dynamic landscape of science and technology sets the stage for a holistic and forward-thinking approach to learning. Chemistry education, in particular, becomes a conduit through which students absorb theoretical knowledge and develop the cognitive tools necessary to grapple with real-world challenges. The classroom thus transforms into a training ground where students hone their ability to think critically, a skill that transcends disciplinary boundaries and becomes a cornerstone for informed decision-making in diverse facets of life.

Ennis' work investigated the correlation between critical thinking skills and academic success in various educational contexts, revealing a positive relationship[1]. Facione's research further emphasized the crucial role of education in fostering critical thinking skills and equipping students with the ability to evaluate information effectively[2]. Additionally, Abrami et al. conducted a meta-analysis highlighting the positive impact of teaching strategies on critical thinking skills, providing valuable insights into effective pedagogical practices[4]. Several studies explored the connection between laboratory experiences and developing critical thinking skills in science education[5][6], offering practical implications for chemistry educators.

Developing students' critical thinking skills within the classroom hinges on the teacher's role, including implementing learning models that stimulate critical thinking, problem-solving abilities, science process skills, and learning motivation. When students are actively engaged in thinking critically to analyze and resolve problems, the construction of knowledge becomes more meaningful. Students' critical thinking ability is assessed using indicators, including elementary clarification, the basis for decision-making, inference, advanced clarification, and supposition and integration.**

The pivotal role of teachers in fostering students' critical thinking skills is well-documented [7]. Implementing learning models targeting critical thinking, problem-solving, and science process skills has enhanced learning motivation [8]. Actively engaging students in critical thinking exercises is a cornerstone of this approach, leading to a more profound construction of knowledge [9].

The obstacles students face in learning chemistry are multifaceted, with motivation playing a pivotal role in hindering a comprehensive understanding of chemical materials[10][11][12]. The lack of motivation can be a significant barrier, impeding the absorption and assimilation of complex chemical concepts.

A critical issue contributing to the challenges in chemistry education is the weak mastery of fundamental concepts. Students often encounter difficulties grasping the foundational principles of chemistry, which hampers their ability to connect these concepts with the world around them. The foundational understanding of chemical materials is crucial for students to contextualize the information and apply it to real-world scenarios[13][14][15].

Moreover, the struggle to connect abstract chemical concepts and their practical implications in the environment exacerbates the learning challenges. The disconnect between classroom learning and real-world application leaves students grappling with the relevance of the subject matter[16][17][18]. This disconnect can lead to a superficial understanding of the material, hindering the development of a deeper, more meaningful comprehension.

The difficulty in concluding presented materials compounds the challenges faced by students. Without a solid grasp of fundamental concepts and the motivation to engage with the material, students may find extracting meaningful insights and conclusions from their chemistry studies challenging. This limitation impacts academic performance and inhibits the development of critical thinking skills, which are essential for analyzing and solving problems in chemistry and beyond.

In addressing these challenges, educators play a pivotal role in designing instructional approaches that not only enhance conceptual understanding but also ignite and sustain students' motivation[19][20][21]. By bridging the gap between abstract concepts and real-world applications, educators can foster a more engaging and relevant learning experience. This, in turn, can contribute to developing students' critical thinking skills and a holistic understanding of chemistry that extends beyond the classroom.

Given the challenges, it becomes imperative to implement a learning model that addresses these issues and actively stimulates students to improve their critical thinking skills, problem-solving abilities, and overall motivation for learning. In response, the study adopts the Problem-Based Learning (PBL) model, a pedagogical approach renowned for fostering students' thinking skills within problem-solving contexts.

The Problem-Based Learning (PBL) model emphasizes high-order thinking, particularly critical thinking, in problem-solving and decision-making processes[22]. Critical thinking is pivotal in effectively navigating problem-solving scenarios, highlighting the necessity of cultivating this cognitive skill in educational practices [22], [23].

Furthermore, Tan accentuates the core principles of problem-based learning by underlining its focus on challenges[24]. Problem-based learning, according to Tan, deliberately presents students with challenges that demand not only surface-level comprehension but also require deep thinking and analysis to formulate viable solutions. This aligns with the broader goal of developing students' critical thinking skills, as the ability to engage in profound cognitive processes is essential for effective problem-solving [23].

The findings from the research [25] shed light on the positive outcomes associated with implementing environment-based chemistry learning using the Problem-Based Learning (PBL) model. According to their study, there is a notable impact on both students' conceptual understanding and critical thinking skills. The experimental class, which experienced integrating environment-based chemistry learning with the PBL model, exhibited a significantly higher average final test score (77.35%) than the control class (62.19%). This disparity in test scores implies that students exposed to the PBL model demonstrated a more comprehensive grasp of the material, showcasing the efficacy of the learning approach in fostering deeper understanding and critical thinking [25].

Similarly, Ismulyati et al. conducted a study that aligns with the positive outcomes of environment-based Problem-Based Learning (PBL). Their research demonstrated that the application of environment-based PBL learning not only resulted in improved student learning outcomes but also increased engagement, positive attitudes, and enhanced learning skills. The completeness of student learning outcomes, as measured through post-test questions at the end of the learning process, was reported to be 88.57%. This suggests a considerable enhancement in students' mastery of the subject matter when exposed to the environment-based PBL learning model [26].

These cumulative findings [25][26]underscore the effectiveness of integrating the Problem-Based Learning model into environment-based chemistry education. The observed improvements in test scores and overall learning outcomes highlight the potential of this pedagogical approach to not only deepen students' understanding of the subject matter but also enhance critical thinking skills, engagement, and positive attitudes toward learning. As such, using the environment-based PBL model emerges as a promising avenue for elevating the quality and effectiveness of chemistry education.

This study focuses on the reaction rate material, a challenging aspect of chemistry that demands conceptual understanding. The choice of this material is strategic, as it necessitates critical thinking skills for comprehension. Effective teaching techniques, such as presenting numerous problems, can aid in conveying the material effectively. The learning process is linked to environmental issues, encouraging students to apply their thinking skills to solve environmental problems. The PBL learning model is anticipated to facilitate material mastery and foster critical thinking skills, enabling students to express opinions and ideas freely while addressing environmental issues [27].

Despite the existing body of research on critical thinking skills in chemistry education, there remains a research gap concerning the specific challenges students face in comprehending complex chemical materials, particularly the reaction rate material. Limited studies have delved into the intricacies of students' struggles with this specific aspect of chemistry and how it relates to their critical thinking abilities. Additionally, while the positive impact of Problem-Based Learning (PBL) on critical thinking skills has been established, there is a need for further investigation into its effectiveness in the context of environment-based reaction rate materials. This research addresses these gaps by providing a nuanced understanding of the challenges students encounter in learning reaction rate material and how the PBL model influences their critical thinking abilities in this domain.

This research contributes to the existing body of knowledge by focusing on the intersection of critical thinking skills, chemistry education, and the specific challenges presented by reaction rate materials. The novelty lies in the targeted exploration of students' difficulties in understanding reaction rate material and how the innovative Problem-Based Learning (PBL) model can effectively address these challenges. Additionally, incorporating environmental issues into the learning process adds a distinctive dimension, encouraging students to apply critical thinking skills to real-world problems. The research aims to provide insights beyond the conventional boundaries of chemistry education, offering practical implications for educators seeking effective strategies to enhance student's critical thinking abilities in challenging chemical concepts.

2. Materials and Methods

The methodology employed in this study draws on established research practices and ethical considerations to investigate students' critical thinking skills using the Problem-Based Learning (PBL) model in the context of the environment-based reaction rate system.

2.1. Population and Sampling

The population for this research encompassed all eleventh-grade students in the science field at Public Senior High School 109 Jakarta during the odd semester of the 2021/2022 academic year. Purposive sampling, a recognized technique in educational research [28], was applied to select students based on predefined criteria relevant to the study's objectives.

2.2. Research Questions

The research questions were formulated to guide the investigation:

1) What is the students' critical thinking skill level in the environment-based reaction rate system?
2) How does the Problem-Based Learning (PBL) model influence critical thinking skills in the context of the environment-based reaction rate system?

2.3. Data Collection

Data were collected by administering tests designed to evaluate critical thinking skills. The test items aligned with established indicators, including elementary clarification, the basis for decision-making, inference, advanced clarification, and supposition and integration. This methodology is consistent with established frameworks for assessing critical thinking skills [1].

2.4. Data Analysis

Quantitative descriptive analysis was employed to interpret the collected data. Descriptive statistics, including measures of central tendency and distribution, were used to summarize the critical thinking scores among the sampled students. This approach aligns with recognized practices in educational research [29].

2.5. Ethical Considerations

Ethical standards were rigorously adhered to throughout the research process. Informed consent, a fundamental ethical principle in educational research, was obtained from participating students. Privacy and confidentiality of data were upheld following established ethical guidelines.

3. Results and Discussion

This study delves into assessing students' critical thinking skills, employing a problem-based learning model in the context of environment-based reaction rates. The research transpired at Public Senior High School 109 Jakarta, involving a cohort of 35 students, composed of 24 girls and 11 boys. The evaluation aimed to gauge the impact of the learning model on students' ability to think critically, offering valuable insights into the dynamics of this pedagogical approach.

Data was collected online, leveraging Google Classroom and Google Meetings. The online environment facilitated the administration of critical thinking skills tests consisting of 10 essay questions. These questions were meticulously crafted to align with Ennis's five critical thinking indicators: elementary clarification, building basic skills, drawing conclusions, providing further explanation, and employing strategies and tactics [30]. The selection of these indicators provided a comprehensive framework for assessing various facets of students' critical thinking abilities.

The study cohort represented a diverse group, encompassing both genders, with a distribution of 24 girls and 11 boys. This gender-inclusive sampling aimed to capture a holistic view of how students, regardless of gender, respond to the problem-based learning model in the context of environment-based reaction rates.

The critical thinking ability test served as a robust instrument, tapping into distinct dimensions of critical thinking [30]. These dimensions include providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and employing strategies and tactics. The multifaceted nature of the assessment aimed to unravel nuanced insights into the student's cognitive processes and problem-solving strategies.

Conducting the study in an online environment through Google Classroom and Google Meetings reflects the adaptability of educational research methodologies to the evolving landscape of digital learning. This approach aligns with contemporary teaching modalities and acknowledges the prevalent use of technology in educational settings.

In the subsequent sections of the analysis, the study will delve into the outcomes of the critical thinking skills assessment, shedding light on the students' performance, challenges encountered, and potential implications for refining the problem-based learning model in chemistry education.

A validity test was conducted using the product-moment correlation to ascertain the effectiveness of the critical thinking skills assessment. Out of the 12 questions designed to measure critical thinking skills, the analysis identified 10 questions as valid. The decision criterion employed was that the item was deemed valid if the calculated correlation coefficient (r_count) was equal to or greater than the tabled correlation coefficient (r_table). This rigorous validation ensured the selected questions accurately measured the targeted critical thinking skills.

The reliability of the assessment instrument was evaluated using the Alpha Cronbach method, yielding a robust result of 0.86. Examining this value within the reliability range criteria [31], the instrument demonstrated a high-category reliability rate. This high-reliability score attests to the consistency and dependability of the critical thinking skills assessment tool. Consequently, the instrument's suitability for gauging students' critical thinking abilities in the context of environment-based reaction rates was confirmed.

These meticulous validity and reliability assessments underscore the methodological rigor employed in this study. The robustness of the assessment instrument establishes a solid foundation for drawing meaningful insights into students' critical thinking skills, contributing to the credibility and trustworthiness of the study's findings.

The analysis of critical thinking skills among students at Public Senior High School 109 Jakarta, particularly in the context of chemistry lessons on environment-based reaction rates, revealed noteworthy insights. At 56.07%, the average percentage falls within the fairly critical category. This categorization aligns with the standard critical thinking skills score, where an average percentage ranging from 40% to 60% is considered fairly critical [32].

The placement of students in the fairly critical category suggests a moderate level of proficiency in critical thinking skills. While they demonstrate a commendable grasp of critical thinking concepts, there is room for improvement and refinement. This nuanced understanding allows educators to tailor instructional strategies to address areas requiring enhancement.

Notably, some students expressed concerns about the allocated time and the perceived difficulty of the questions. This feedback provides valuable context to the analysis, indicating potential challenges students face. The assertion that questions related to environmental indicators of critical thinking were unfamiliar implies a need for further exposure and practice in this specific cognitive domain.

The data distribution on students' critical thinking abilities is visually represented in Figure 1.

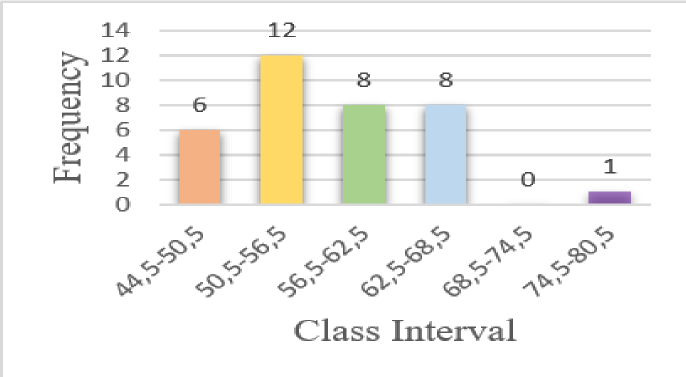

Figure 1. Histogram of the Frequency Distribution of Critical Thinking Skills

Figure 1 offers a graphical representation of the distribution of critical thinking abilities among students, providing insights into the range and concentration of test scores. The following key observations can be made:

The distribution spans from the lowest score range of 45-50, where 6 students scored, to the highest score range of 75-80, with 1 student achieving this top score. The most frequently obtained scores, the mode, are clustered in the 51-56 range. This range is represented by a substantial number of students, totaling 12.

Notably, there is a presence of high test scores in the 75-80 range. While only 1 student falls into this category, it indicates an exceptional level of performance in critical thinking.

The distribution pattern visually represents how students' critical thinking abilities are spread across different score ranges. The concentration in certain ranges and the spread to lower and higher scores contribute to the overall understanding of the cohort's performance.

Table 1. Percentage of Critical Thinking Skills Indicators

No	Indicator	Percentage	Category
1	Gives a Simple Explanation	68.57%	Critical
2	Determining the Basis for Decision-Making	56.71%	Quite Critical
3	Draw a conclusion	52.85%	Quite Critical
4	Provide Further Explanation	56.42%	Quite Critical
5	Tactics and Strategy	46.42%	Quite Critical

Average	56.16%	Quite Critical

Based on the table above, it can be concluded that the indicator providing a simple explanation is the indicator that has the largest percentage in this study, namely, with a score of 68.57%. This indicates that the indicator providing a simple explanation is included in the critical category. In test analysis, the average student can identify and analyze the questions in the questions well, as can be seen from the students' answers, which can relate existing phenomena to the factors that affect the rate of reaction. According to Schafersman, someone who thinks critically can identify questions, collect relevant information, act efficiently and creatively based on the information, and draw reliable conclusions [33]. Based on these statements, students who think critically are students who can identify a problem and provide statements based on reliable information.

Determining the basis for decision-making with sub-indicators considering the credibility of a source has a percentage of 56.71%, including the quite critical category. One of them concerns the impact of carbide in fruit ripening and other problems associated with factors affecting the reaction rate. Students can already provide answers correctly regarding the phenomenon associated with factors that affect the rate of reaction based on reliable information. However, many students still have difficulty sorting information that can be trusted. Much inaccurate information can be seen from student answers that do not follow the problem to be solved concerning the factors that affect the reaction rate.

The indicator draws the conclusion that the percentages generated based on research results are classified as indicators that are quite critical, namely only around 52.85%. In this indicator, students are given several statements related to the results of the reaction order experiment, and then students are asked to provide conclusions based on these statements. Based on the data from the test analysis results, students are quite good at interpreting statements or making conclusions from general to specific (deduction) based on the problems given. However, some students had difficulty concluding a statement given in the essay questions. This can be seen from the answers of students who have not been able to conclude based on all the information in the question.

The indicator further explains the percentage generated based on the research results. It is also classified as a fairly critical indicator, only around 56.42%. The sub-indicators used are indicators that identify assumptions. Constructing an argument is the goal of the indicator to identify assumptions. In identifying assumptions, students need reasoning about an event presented in the problem to construct arguments and make appropriate conclusions. Based on the data from the test analysis results, the average student can identify the assumptions of the problems caused by the acid rain phenomenon, which are associated with factors that affect the reaction rate in detail. However,some students were not quite right in answering the question. This can be due to the different reasoning power of each student to produce different thoughts. Reasoning is an activity of thinking to produce a conclusion. Subjective factors and objective factors can influence a person's thinking process. This causes human understanding of the same phenomenon to produce different conclusions.

The percentage of tactics and strategy indicators generated based on research results are classified as low indicators, namely only around 46.42%. The sub-indicators used are indicators that determine an action. This indicator is measured through a test by selecting possible criteria as a solution. Based on the data from the test analysis results, the average student has not been able to determine an action to find a solution to a problem correctly. One of the problems regarding the catalysts in motorized vehicles is that students have not been able to explain the types of catalysts used and the role of these catalysts in the environment. However, some students were able to explain the solution to the problem. Students who are trained in expressing their ideas in Problem-Based Learning will find it easy to find solutions to a problem. This follows the theory that Problem-Based Learning is a learning approach that uses problems close to the environment as a context for students to learn problem-solving skills [34]–[37].

The indicator determines the basis for decision-making to obtain the second-highest percentage. This indicator makes students give statements based on accurate information according to the problem to be solved. Next is an indicator of tactics and strategies that show students' ability to decide or provide a solution to a problem correctly. This indicator gets the third highest percentage in the very critical category. Then, the indicator provides further explanation of obtaining the second lowest percentage. The last indicator provides a simple explanation of obtaining the lowest percentage. Based on the previous explanation, the analysis of student's critical thinking skills tests obtained different percentages for each indicator of critical thinking skills. This can be caused by students not being accustomed to understanding the reaction rate material associated with existing environmental problems[38]. In addition, the current condition of learning activities that are less effective because they are still implementing online learning and students' different critical thinking abilities cause this to happen [39]. This aligns with other research on the effectiveness of using environment-based Problem-Based Learning [40]–[43].

4. Conclusion

Based on the research findings and discussions regarding students' critical thinking skills using the Problem-Based Learning (PBL) model on environment-based reaction rates, it is concluded that students' critical thinking skills fall within the moderately critical category. The results indicate varying percentages for each critical thinking skills indicator: providing simple explanations (68.57%), determining the basis for decision-making (56.71%), providing further explanations (56.42%), drawing conclusions (52.85%), and tactics and strategy (46.42%). Consequently, it can be inferred that, in the context of environment-based reaction rates and the implementation of the Problem-Based Learning model, certain students exhibit increased engagement in online learning activities, enhancing their critical thinking processes.

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