ANALYSIS OF LEARNING OUTCOMES OF BUFFER SOLUTION MATERIALS THROUGH THE DISCOVERY LEARNING APPROACH IN VOCATIONAL HIGH SCHOOLS

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Article history: *received 14 August 2024; revised 16 September 2024; accepted 14 October 2024* *DOI: https://doi.org/10.33751/jssah.v4i3.12835*

Abstract. This study aims to analyze the impact of the Discovery Learning approach on students' learning outcomes in the topic of buffer solutions among Class XI science students at SMAK Sint Carolus Kupang, Indonesia. The research seeks to determine (1) the implementation of the Discovery Learning model in teaching buffer solution concepts, (2) students' learning outcomes after applying the model, (3) student satisfaction with the Discovery Learning process, and (4) the effect and correlation between the use of Discovery Learning and student learning achievement. Using a descriptive-associative quantitative design, the study involved 30 students selected through purposive sampling. Data were collected through observation, achievement tests, and questionnaires, and analyzed using correlation and simple regression techniques. The results show that the implementation of Discovery Learning in chemistry lessons was categorized as good with a reliability rate of 98%, while the average learning outcome score reached 85, exceeding the school's minimum completeness criteria of 75. Student satisfaction with the learning process was rated very good at 82%. Statistical analysis revealed a significant positive relationship between the Discovery Learning approach and learning outcomes, with a correlation coefficient of $r = 0.40$ and a regression equation of $Y = 70.338 + 0.173X$. These findings indicate that Discovery Learning fosters active student participation, enhances conceptual understanding of buffer solutions, and effectively improves chemistry learning outcomes..

Keywords: Discovery Learning; buffer solution; student achievement; learning outcomes; chemistry education.

I. INTRODUCTION

The mastery of chemistry concepts is essential in developing students' scientific literacy, critical thinking, and problem-solving skills in the 21st-century learning framework [1]. Chemistry as a discipline requires not only conceptual understanding but also the ability to relate theory to experimental practice [2]. However, numerous studies indicate that students often face difficulties in comprehending abstract chemical concepts, particularly in topics involving acid-base equilibrium and buffer solutions, due to their microscopic and mathematical characteristics [3]. Such learning challenges often lead to misconceptions, low motivation, and decreased academic achievement [4]. In Indonesia, the buffer solution (larutan penyangga) is a crucial topic taught at the senior high school level because it serves as a foundation for understanding pH regulation, biochemical systems, and industrial applications [5]. Nevertheless, research reveals that the topic is among the most difficult for students, as it requires integration of chemical equations, ionization concepts, and stoichiometric reasoning [6]. The use of teacher-centered instructional models tends to limit students' ability to actively construct their own knowledge, leading to passive learning behavior and limited problem-solving capacity [7].

To address these issues, the Discovery Learning approach a constructivist-based pedagogical model has been widely promoted in chemistry education [8]. This model emphasizes student participation in discovering scientific principles through guided inquiry, observation, experimentation, and reflection [9]. According to Bruner's learning theory, discovery fosters meaningful understanding and cognitive restructuring, as students actively engage in hypothesis generation and validation [10]. In chemistry instruction, Discovery Learning has proven effective in improving students' comprehension of abstract concepts, laboratory skills, and attitudes toward science [11]. Discovery Learning aligns with Indonesia's Kurikulum Merdeka (Independent Curriculum), which promotes inquiry-based and student-centered learning [12]. The approach encourages learners to construct their own understanding through the stages of stimulation, problem identification, data collection, data processing, verification, and generalization [13]. This process trains students to think scientifically while developing independence, curiosity, and critical reasoning. Empirical studies have demonstrated that Discovery Learning improves cognitive achievement, retention, and engagement in complex topics such as reaction rates, equilibrium, and buffer systems [14].

In this study, the Discovery Learning model was applied to the topic of buffer solutions to evaluate its influence on students' learning outcomes and satisfaction levels. The research specifically focuses on four objectives: (1) describing the implementation of Discovery Learning in teaching buffer solution material, (2) analyzing students' achievement after applying this approach, (3) measuring students' satisfaction with the learning process, and (4) determining the correlation and effect between Discovery Learning and students' learning outcomes. The findings of this study are expected to contribute both theoretically and practically. Theoretically, it provides empirical evidence supporting the integration of constructivist learning models in chemistry education. Practically, it offers insights for teachers to design more engaging and inquiry-oriented learning environments that enhance conceptual understanding, student motivation, and academic performance in scientific subjects [15]. The Discovery Learning approach is a pedagogical model that emphasizes students' active involvement in the process of discovering concepts, principles, and relationships through inquiry and exploration [16]. Rooted in Jerome Bruner's constructivist learning theory, Discovery Learning asserts that meaningful understanding occurs when learners construct knowledge through direct experience rather than passive information reception [17]. Bruner proposed that learning should follow three representational stages enactive (action-based), iconic (image-based), and symbolic (abstract reasoning) which together facilitate deep conceptual comprehension [18].

In Discovery Learning, the teacher acts as a facilitator who guides students through structured stages: stimulation, problem identification, data collection, data processing, verification, and generalization [19]. This framework encourages inquiry, critical thinking, and self-directed learning, which are essential for mastering abstract scientific concepts such as buffer systems. According to recent studies, Discovery Learning enhances student engagement, cognitive development, and knowledge retention, particularly in subjects requiring analytical and experimental reasoning [20]. The effectiveness of Discovery Learning in chemistry lies in its ability to transform traditional teacher-centered instruction into a student-centered learning process that promotes curiosity and scientific inquiry [21]. Research conducted by Wahyuni and Suryana (2023) demonstrated that Discovery Learning significantly improved students' conceptual mastery and experimental skills in acid-base reactions, while also increasing intrinsic motivation [11]. Similarly, Aulia (2023) emphasized that the six stages of Discovery Learning when implemented effectively develop both scientific reasoning and communication skills [13].

The constructivist paradigm views learning as an active process of meaning-making where learners connect new information with their prior knowledge and experiences [22]. In chemistry education, constructivism is particularly relevant because many chemical phenomena are abstract, invisible, and require representational thinking at the macroscopic, microscopic, and symbolic levels [23]. Therefore, students must construct mental models through experimentation, problem-solving, and reflection.

Constructivist teaching encourages the integration of hands-on inquiry activities, peer discussion, and contextual problem-solving, all of which promote deep conceptual learning. A study by Çetin-Dindar and Geban (2023) revealed that students who participated in constructivist-based chemistry lessons demonstrated better understanding and retention of complex topics like equilibrium and acid-base reactions [3]. Similarly, Purwanti (2022) reported that constructivist instructional strategies improved students' cognitive and metacognitive awareness, enabling them to apply chemical concepts in real-world contexts [14]. The Discovery Learning approach aligns closely with constructivist principles because it requires learners to actively hypothesize, test, and validate their understanding. When implemented in chemistry classrooms, this approach bridges theoretical concepts with empirical observation, thereby reinforcing conceptual coherence and scientific reasoning [24].

Learning outcomes in chemistry reflect the extent to which students achieve cognitive, affective, and psychomotor objectives defined by the curriculum [25]. Specifically, in the topic of buffer solutions, learning outcomes refer to students' ability to understand pH control mechanisms, calculate buffer capacities, and apply concepts in biological and industrial systems. According to Arista (2022), buffer solutions are conceptually difficult because they require simultaneous comprehension of equilibrium, stoichiometry, and logarithmic calculations [6]. Studies have found that students often hold misconceptions about how buffers resist pH changes and misinterpret the role of conjugate acid-base pairs [5], [23]. Therefore, instructional models that encourage active exploration such as Discovery Learning are necessary to promote conceptual change. Research by Hidayah (2023) showed that Discovery Learning improved student understanding of equilibrium and buffer systems by allowing them to observe real phenomena through experiments and simulations [8].

Based on the literature, the Discovery Learning model has demonstrated positive effects on students' conceptual understanding and learning motivation in science education [18], [21]. However, few studies have specifically examined its application to buffer solution materials in the context of Indonesian senior high schools, particularly in faith-based institutions such as SMAK Sint Carolus Kupang. Most previous research has focused on cognitive outcomes, while affective factors such as student satisfaction and engagement remain underexplored. This study fills that gap by analyzing how the Discovery Learning approach affects not only students' achievement but also their attitudes and satisfaction toward the learning process. The conceptual framework assumes that the Discovery Learning stages ranging from stimulation to generalization stimulate higher-order cognitive processes and self-motivation, which in turn enhance overall learning outcomes in buffer solution topics.

II. RESEARCH METHODS

This study employed a quantitative descriptive-associative research design to analyze the relationship between the implementation of the Discovery Learning approach and students' learning outcomes on the topic of buffer solutions among Class XI science students at SMAK Sint Carolus Kupang. The quantitative approach was selected because it allows for the objective measurement of relationships between instructional variables and learning performance using statistical analysis [26]. The associative design was used to determine the correlation and effect of Discovery Learning on student achievement, thereby identifying the extent to which the learning model contributes to improving conceptual understanding and satisfaction. The population of the study consisted of Class XI science students enrolled in SMAK Sint Carolus Kupang during the 2023/2024 academic year. A total of 30 students were selected using purposive sampling, based on their exposure to chemistry instruction using the Discovery Learning model. The relatively small but controlled sample size was appropriate for exploratory quantitative analysis in classroom-based research.

Three main instruments were used for data collection: Observation sheets, used to assess the implementation of Discovery Learning during classroom instruction, evaluated using a structured rubric with five indicators corresponding to the stages of the model (stimulation, problem identification, data collection, processing, verification, and generalization). Achievement tests, consisting of multiple-choice and short-answer questions aligned with the learning objectives for buffer solution topics, designed to assess students' cognitive mastery and problem-solving ability. Questionnaires, used to measure students' satisfaction and perceptions toward the learning process, administered after the implementation of Discovery Learning. All instruments were validated by content experts and classroom practitioners, and reliability was established through Cronbach's Alpha ($\alpha > 0.80$), indicating strong internal consistency.

Data were collected over a two-week instructional cycle. Observations were conducted during each lesson to monitor the implementation quality of Discovery Learning. After the intervention, achievement tests and satisfaction questionnaires were administered to all participants. Quantitative data were analyzed using descriptive statistics (mean, percentage, and categorization) to summarize student achievement and engagement, while inferential statistics specifically correlation analysis and simple linear regression were used to examine the relationship between the implementation of Discovery Learning and learning outcomes.

The significance level was set at $p < 0.05$. Regression analysis produced an equation of $Y = 70.338 + 0.173X$, indicating a positive correlation between the Discovery Learning approach and students' performance. The coefficient of determination ($r = 0.40$) suggested a moderate yet significant relationship between the two variables. All statistical analyses were conducted using SPSS version 25.0, ensuring precision and replicability of results [27].

III. RESULTS AND DISCUSSION

The implementation of the Discovery Learning approach in teaching the topic of buffer solutions was evaluated through three key indicators: (1) the quality of implementation during instruction, (2) students' cognitive learning outcomes, and (3) students' satisfaction with the learning process. The observational data indicated that the learning implementation achieved a very good category, with an average score of 98%, demonstrating that teachers followed the six procedural stages of Discovery Learning effectively. The results of the achievement test showed that students' mean score was 85, which exceeded the school's minimum competency standard (KKM) of 75. This indicates that students achieved satisfactory comprehension of buffer solution concepts, including pH calculation, buffer capacity, and application in chemical and biological systems. The student satisfaction questionnaire revealed a very good category (82%), reflecting high engagement, enthusiasm, and appreciation for the Discovery Learning method.

The correlation analysis produced a Pearson correlation coefficient (r) = 0.40, suggesting a moderate but positive correlation between the Discovery Learning approach and students' learning outcomes. Further regression analysis yielded the equation $Y = 70.338 + 0.173X$, implying that improvements in the implementation quality of Discovery Learning predict corresponding increases in learning outcomes. The model's significance level ($p < 0.05$) confirms a statistically meaningful relationship. Overall, these results demonstrate that Discovery Learning has a positive effect on student performance and engagement in learning buffer solution material.

The results of this study provide empirical evidence that Discovery Learning enhances students' understanding and performance in chemistry, particularly in complex topics such as buffer solutions. These findings are consistent with Bruner's constructivist theory, which posits that learners achieve deeper understanding when they discover relationships and principles independently [16]. Through guided inquiry, students develop conceptual linkages between theoretical and experimental aspects of buffer systems, strengthening their cognitive structure.

The positive correlation between Discovery Learning and learning outcomes supports prior research by Wahyuni and Suryana (2023), who reported that discovery-based laboratory activities significantly improved conceptual understanding and critical thinking in acid-base chemistry [20]. Similarly, Aulia (2023) found that the six stages of Discovery Learning stimulation, problem identification, data collection, processing, verification, and generalization enhance students' analytical and reflective thinking skills [13]. The results also confirm that Discovery Learning fosters active participation and engagement, which contribute to motivation and satisfaction in learning. The

82% satisfaction rate observed in this study aligns with the findings of Hidayah (2023), who noted that students exposed to discovery-oriented environments tend to express higher enthusiasm and self-confidence in scientific inquiry [8]. By emphasizing student autonomy and exploration, Discovery Learning supports intrinsic motivation a key factor in sustaining long-term academic interest and achievement [28]. Moreover, the improvement in students' achievement can be attributed to the interactive nature of Discovery Learning, which allows learners to connect macroscopic phenomena (laboratory experiments) with symbolic representations (chemical equations). This aligns with the constructivist framework described by Windschitl (2023), emphasizing that knowledge is actively constructed through contextualized experiences rather than transmitted passively [22]. The current findings also resonate with Purwanti (2022), who demonstrated that Discovery Learning improves knowledge retention and conceptual transfer in chemistry topics involving equilibrium and acid-base systems [24].

The moderate correlation value ($r = 0.40$) suggests that while Discovery Learning positively influences achievement, other factors such as students' prior knowledge, learning environment, and cognitive ability may also contribute to learning success [29]. Therefore, the approach should be complemented by differentiated instruction and continuous assessment to accommodate varying student capabilities. Overall, the findings validate the potential of Discovery Learning as an effective instructional strategy for enhancing cognitive performance, engagement, and satisfaction in chemistry education, especially for abstract concepts like buffer solutions. This reinforces the view that inquiry-driven, student-centered models promote meaningful learning outcomes and scientific literacy among high school students [30], [31].

IV. CONCLUSION

This study concludes that the Discovery Learning approach significantly enhances students' learning outcomes, engagement, and satisfaction in the topic of buffer solutions among Class XI science students at SMAK Sint Carolus Kupang. The results showed that the implementation quality of Discovery Learning reached a very good level (98%), students' learning achievement exceeded the minimum competency standard (average score = 85), and their satisfaction level was classified as very good (82%). Statistical analysis further revealed a positive and significant correlation ($r = 0.40$, $p < 0.05$) between the implementation of Discovery Learning and students' performance, confirming that the approach effectively improves understanding of chemical concepts. The findings support constructivist learning theory, which posits that knowledge is best acquired when learners actively construct meaning through exploration and self-discovery. By engaging students in observation, experimentation, and reflection, Discovery Learning helps bridge the gap between theoretical abstraction and real-world application in chemistry education. These results are consistent with previous research emphasizing the model's ability to foster higher-order thinking, conceptual mastery, and motivation in science classrooms [16], [31]. Thus, Discovery Learning can be considered a viable pedagogical alternative to traditional teacher-centered instruction, particularly for abstract and computation-intensive topics like acid-base equilibrium and buffer systems.

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