Bioedukasi
Jurnal Biologi dan Pembelajarannya

Vol. 24 No 1, February 2026, page 79-88
e-ISSN: 2580-0094; p-ISSN:1693-3931
DOI: 10.19184/bioedu.v24i1.53770
bioedukasi.jurnal.unej.ac.id

Context-Based Inquiry Learning as an Innovative Strategy in Improving High School Students' Critical Thinking Skills

Aldis Muhammad Hanif[1], Jujun Ratnasari[2], Setiono[3]
[1,2,3]Biology Education, University of Muhammadiyah Sukabumi, Indonesia

Article Info
Article history:
Received January 31, 2026
Revised February 28, 2026
Accepted February 28, 2026
Published February 28, 2026

Keywords:
Context-based inquiry learning
Critical thinking
Plant species diversity

ABSTRACT

This study investigated the effectiveness of the Context-Based Inquiry Learning (CBIL) model in improving high school students' critical thinking skills in plant diversity. CBIL integrates real-life contexts with structured scientific inquiry processes to promote analytical and reflective thinking. A quasi-experimental design with a non-equivalent control group was employed, involving 69 tenth-grade students from a public senior high school in Sukabumi City selected through purposive sampling. The experimental group received CBIL instruction, while the control group received discovery-based instruction. Instruments included a critical thinking skills test, an attitude scale, and a student response questionnaire. The results showed that the experimental group achieved a higher average N-Gain score (0.81 ± 0.10, high category) compared to the control group (0.53 ± 0.10, moderate category). An independent-samples t-test indicated a statistically significant difference between groups ($p < 0.05$). Supporting data revealed positive critical thinking attitudes and very favorable student responses (91.18% ± 12.04). These findings demonstrate that CBIL is an effective, contextually grounded instructional approach for enhancing students' critical thinking skills in biology.

Corresponding Author:
Jujun Ratnasari,
Biology Education, University of Muhammadiyah Sukabumi
Jalan R. Syamsudin, SH. No 50, Sukabumi 43113, Indonesia
Email: jujun.ratnasari@ummi.ac.id

1. INTRODUCTION

The current education system must be equipped to address global challenges that are presented in every aspect of our lives. Education that aligns with environmental, social, and economic conditions and needs is crucial for better preparing students for their future lives [1], [2], [3], [4]. Transformation in the 21st century requires students to possess higher-order thinking skills, especially critical thinking, as a foundation for solving complex problems, making informed decisions, and evaluating information objectively and reflectively [5], [6]. Critical thinking skills are essential competencies in shaping a resilient generation in facing global challenges, including technological developments, disinformation, and complex socio-cultural dynamics [7], [8], [9], [10], [11]. Importantly, critical thinking skills are not limited to academics but are an important foundation in everyday life, guiding individuals in making logical decisions based on relevant evidence [12], [13], [14].

The results of the 2022 PISA study indicate that students in Indonesia still exhibit low critical thinking skills, as reflected in a scientific literacy score of 383, which is significantly below the OECD average of 485 [15]. While this is a concerning finding, it also presents an opportunity for significant improvement. This low score reflects the learning conditions in schools that still prioritize mastery of material and memorization over the development of reasoning and argumentation skills [16], [17]. Strengthening critical thinking skills to address real-world problems is a top priority on the 21st-century education agenda. However, the integration of learning approaches that support these skills still faces various obstacles in many schools. Classroom learning is generally still dominated by one-way lecture methods, which make students passive recipients of information rather than active participants in the learning process [18], [19], [20]. This is exacerbated by the low pedagogical abilities of teachers in implementing innovative learning models that encourage reflective participation [21].

Through interviews and field observations with a high school teacher in Sukabumi City, we have gathered information that underscores the importance of your role in implementing effective learning models. The teacher revealed that the current models have not been successful in fostering students' critical thinking skills. The observation results further confirm this, showing that the critical thinking skills of 10th-grade students are at a concerning low. This situation calls for your active involvement in the development and implementation of targeted learning models that can sharpen and enhance students' critical thinking skills.

The problem of students' low critical thinking skills cannot be addressed solely through conceptual approaches; instead, it requires an applicative approach that is relevant to real-world conditions in the learning context. Although various learning models, such as problem-based learning, project-based learning, and cooperative learning, have been introduced into the curriculum, their implementation still faces various obstacles, such as limited teacher pedagogical competence, a lack of facilities and infrastructure, and limited time allocation [21]. This situation creates a gap between education policy and practice, partly due to the lack of learning models that effectively combine everyday life contexts with scientific thinking processes in a holistic approach [22], [23].

The need to strengthen critical thinking skills is increasingly important in today's era of digital disruption and globalization. Countries like Finland and Canada have successfully adopted inquiry-based and context-based approaches to science education, engaging students in real-world problem-solving, experimentation, and reflection [24], [25], [26], [27]. These strategies have proven effective in significantly enhancing students' motivation to learn, their conceptual understanding, and their critical thinking skills [28]. However, in Indonesia, the implementation of these approaches remains limited due to several obstacles, including insufficient teacher training, time constraints, and an evaluation system that predominantly focuses on lower-level cognitive skills. Therefore, innovative and more contextual strategies, such as context-based inquiry learning, present a promising alternative to promote active and reflective student engagement in the learning process.

The context-based inquiry learning model has emerged as an innovative approach that integrates context-based learning with a scientific inquiry method. This model encourages students to develop a conceptual understanding by exploring real-world situations [29]. A key feature of this model is its use of contextual problems as the initial stimulus for learning. This is followed by various inquiry stages, including formulating questions, conducting experiments, analyzing data, and drawing. This approach not only fosters active student engagement but also provides opportunities for developing critical thinking skills through an authentic scientific process.

The immense potential of context-based inquiry learning in developing critical thinking skills lies in student engagement at every stage of the learning process. The contextual issues raised encourage students to identify real-world problems, formulate critical questions, and develop hypotheses to address them. The experimentation and data analysis phases require students to logically evaluate evidence and compare various possible solutions. Furthermore, the process of drawing conclusions and reflecting on them hones students' ability to synthesize information, evaluate arguments, and make decisions based on relevant evidence. Thus, this model provides a learning experience that integrates understanding of scientific concepts with critical thinking skills, making it more suited to the needs of 21st-century education.

Several researchers support the effectiveness of real-life-based learning models in developing students' critical thinking skills through meaningful learning. As stated in [30] that connecting subject matter to real life can increase students' motivation and interest in learning, which forms the basis for cognitive engagement. This aligns with [31] who emphasized that a context-based inquiry approach encourages active exploration of real phenomena and enhances higher-order thinking processes. As noted in [32], contextual inquiry fosters critical thinking skills through the formulation of hypotheses, data analysis, and conclusion drawing. Furthermore, [33] emphasized that local context-based science learning strengthens students' conceptual understanding, and [34] highlighted that real-life-based inquiry fosters logical as well as reflective evaluative skills. Similarly [35], [36], found that local context-based learning projects can improve students' ability to explain scientific concepts coherently. This highlights the vital role of educators in facilitating real-life-based learning and underscores the significance of their contributions to students' learning outcomes.

While numerous studies have demonstrated the effectiveness of context-based inquiry learning (CBIL) in enhancing critical thinking skills, most focus on general science contexts rather than plant diversity, a topic often taught through memorization-oriented approaches. In addition, prior research typically reports overall critical thinking gains without examining improvements across specific indicators, limiting deeper understanding of how different cognitive dimensions develop. This study advances existing CBIL research by extending its application to plant diversity learning (conceptual contribution), providing indicator-level analysis of critical thinking development (methodological contribution), and situating the intervention within the Indonesian secondary education context, where higher-order thinking remains a national challenge (contextual contribution). Through this integrated approach, the study offers more precise empirical insight into how CBIL fosters structured and measurable cognitive development in biodiversity instruction.

Based on this background, the purpose of this study was to analyze the effectiveness of the context-based inquiry learning model in enhancing students' critical thinking skills related to plant diversity, as well as to examine the differences in achievement levels of each critical thinking indicator between the experimental and control classes. The indicators used have been proven relevant in measuring critical thinking skills in science [37], [38], [39]. By combining real-life contexts and scientific inquiry stages, this model is expected to encourage deeper conceptual understanding while developing higher-order thinking skills [40], [41]. Previous research also indicates that a contextual approach can enhance scientific literacy, foster learning engagement, and deepen the understanding of concepts [29].

This research is expected to contribute to two aspects. Theoretically, it can enrich studies on the effectiveness of context-based inquiry learning, particularly in biology teaching on plant diversity, and provide a more comprehensive picture of the achievement of each critical thinking indicator. Practically, this research can serve as a beacon of hope for teachers, offering them the means to design more meaningful, innovative, and contextually relevant learning strategies that can significantly enhance students' critical thinking skills in line with the demands of 21st-century education.

2. RESEARCH METHOD

This study employed a quasi-experimental method. The intervention was implemented over five weeks, with 45-minute instructional sessions at each meeting, covering the entire plant diversity unit. This duration ensured adequate exposure to the learning model, resulting in measurable improvements in students' critical thinking skills while maintaining comparability between groups. This method is used to determine the causal relationship between independent and dependent variables without requiring a complete randomization process to be applied to the research subjects [42], [43]. The study employed a non-equivalent control group design, an effective quasi-experimental approach involving two groups experimental and control that were not randomly assigned. This design is considered appropriate in situations where complete randomization is not feasible [44]. This design is considered capable of providing an overview of the effectiveness of a learning model despite limitations in controlling external variables.

Table 1. Non-Equivalent Control Group Design Pattern

Class	***Pre-test***	Treatment	***Post-test***
Experimental	Q_1	X_1	Q_2
control	Q_3	X_2	Q_4

Explanation:
Q_1: Pre-test in the experimental class.
Q_2: Post-test in the experimental class
X_1: Implementation of the context-based inquiry learning model
X_2: Application of the discovery learning learning model
Q_3: Pre-test of control class
Q_4: Post-test of control class

The research subjects were grade X students of a public high school in Sukabumi City during the 2024/2025 academic year, with a sample of two classes selected using purposive sampling (Etikan, 2016): X.10 (n = 34, experimental) and X.9 (n = 35, control). The class selection took into account the equality of student numbers, the homogeneity of academic abilities, and the availability of learning facilities.

Table 2. Research Instruments

Instrument	Indicator	Scale	Objective
Critical thinking skills test	Interpretation, Analysis, Evaluation, Inference, Explanation, Self-Regulation	Score 0-100	Measuring cognitive achievement
Attitude scale		Likert five-point	Measuring students' disposition towards critical thinking
Response questionnaire	Interest, Model evaluation, Skills, Material relevance	Four-point Likert	Knowing students' perceptions

The research procedure was carried out in several stages, employing multiple evaluation methods to ensure the thoroughness of the study. First, a pre-test was administered to the experimental and control classes to measure students' initial critical thinking skills. Second, the experimental class received treatment using a context-based inquiry learning model, while the control class underwent conventional learning with a discovery learning model. Third, a post-test was administered to both classes to evaluate improvements in critical thinking skills. Next, an attitude scale questionnaire was used to identify tendencies in critical thinking attitudes, and a response questionnaire was explicitly distributed to the experimental class to determine students' perceptions of the learning implemented.

The primary instrument was a critical thinking skills test developed based on six indicators adapted from the Facione framework: interpretation, analysis, evaluation, inference, explanation, and self-regulation. The test consisted of 12 essay items designed to assess higher-order thinking in plant diversity material and was scored using an analytic rubric (0–4 scale) evaluating conceptual accuracy, reasoning, explanation clarity, and justification, with scores converted to a 0–100 scale. Content validity was established through expert judgment involving three experts in biology education and assessment, and revisions were made accordingly. Construct validity was examined through item difficulty and discrimination analysis. Reliability testing using Cronbach's alpha yielded α = 0.87, indicating high internal consistency. Additionally, an attitude scale (five-point Likert) and a response questionnaire (four-point Likert) were administered and demonstrated acceptable reliability (α = 0.82 and α = 0.85).

The data analysis in this study aimed to address the research questions and evaluate the effectiveness of the context-based inquiry learning model. The analytical procedures included the Shapiro–Wilk test to examine the normality of pre-test and post-test scores, Levene's test to assess the homogeneity of variances, and an Independent Samples t-test to compare the mean critical thinking scores between the experimental and control groups at a significance level of α = 0.05. Learning improvement was analyzed using the normalized gain (N-Gain) to determine the extent of students' progress relative to their initial performance. Meanwhile, data obtained from the attitude scale and student response questionnaires were converted into mean scores and percentages for interpretation. The integration of inferential statistical analysis (t-test and N-Gain) and descriptive percentage analysis provides a comprehensive evaluation of instructional effectiveness, encompassing both cognitive outcomes and students' affective responses toward the learning process.

3. RESULT AND DISCUSSION

The research data obtained were then analyzed using prerequisite tests and hypothesis tests. Prerequisite tests included normality and homogeneity tests, while hypothesis tests were used to determine significant differences between the experimental and control classes.

Table 3. Statistical analysis of the influence of CBIL

Test/Data Type		**Class**		**Explanation**
		Experimental	**Control**	
Mean ± SD	Pre-test	37,94 ± 1,04	38,57 ± 1,06	Initial equivalent ability
	Post-test	87,57 ± 1,3	70,85 ± 1,37	
N-Gain		0,8	0,53	
Normality	Pre-test	0,14	0,63	Normally distributed data
	Post-test	0,13	0,69	
Homogeneity	Pre-test	0,84		Homogen
	Post-test	0,67		
Test T (Sig. 2- Tailed)	Pre-test	0,67		There is no initial difference
	Post-test	0		There is a significant difference
Conclusion	The Context-Based Inquiry Learning learning model is efficacious in improving students' critical thinking skills.			

The results of the study showed that the pre-test and post-test data in both the experimental and control classes were normally and homogeneously distributed, thus meeting the requirements for a t-test. The t-test on the pre-test data yielded a significance value of 0.674 (>0.05), meaning that the initial abilities of both classes were equal. After treatment, the t-test results on the post-test showed a significance value of 0.000 (<0.05), indicating a significant difference between the experimental and control classes. This difference was supported by the N-Gain analysis, which showed that the experimental class achieved a score of 0.8 (high category), while the control class achieved only 0.53 (medium category).

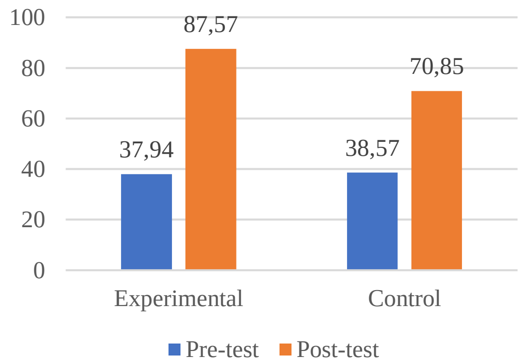

Figure 1. Comparison of Pretest-posttest Values

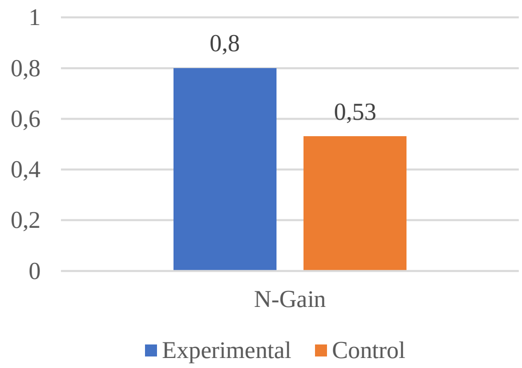

Figure 2. Comparison of N-Gain Values

The analysis results showed that the average pretest scores of the experimental class (37.94) and the control class (38.57) were relatively similar, indicating that the students' initial abilities were equal. After the treatment, the average posttest score of the experimental class increased significantly to 87.57, while the control class reached only 70.85. This difference is increasingly evident in the pretest–posttest comparison diagram (Figure 1), which shows a higher increase in the experimental class. The N-Gain analysis also supported this finding, with a score of 0.8 (high category) in the experimental class and 0.53 (medium category) in the control class (Figure 2). These results not only validate the effectiveness of Context-Based Inquiry Learning in improving students' critical thinking skills but also offer hope for its potential to revolutionize conventional learning methods. This finding is also consistent with the struggles of Indonesian students in developing critical thinking skills, as highlighted earlier [15]. Students in Indonesia have been shown to struggle with critical thinking skills due to rote learning methods [16], [17], and we need to understand and address this issue.

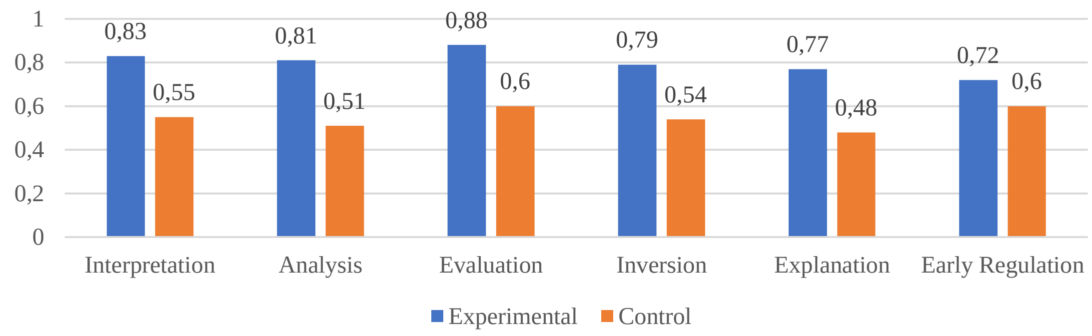

Figure 3. Comparison of N-Gain Values per Indicator

The analysis results showed that all critical thinking indicators experienced a significant increase in the experimental class compared to the control. The N-Gain value and attitude scale questionnaire supported this finding, where the indicators of interpretation (0.83 vs. 0.55), analysis (0.81 vs. 0.51), evaluation (0.88 vs. 0.56), inference (0.79 vs. 0.54), explanation (0.77 vs. 0.48), and self-regulation (0.72 vs. 0.55) were consistently higher in the experimental class. This robust evidence suggests that the Context-Based Inquiry Learning model is highly effective in enhancing the skills of interpreting information, analyzing arguments, evaluating data, drawing conclusions, constructing logical explanations, and engaging in critical self-reflection, with the potential to significantly impact teaching methods and critical thinking development.

These findings align with a recent formulation of critical thinking as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based [37], [39]. The improvement in these indicators is supported by previous research [31], which confirms that inquiry-based contextual learning enhances conceptual understanding and problem-solving by connecting students with real-life experiences. Therefore, the implementation of this model not only impacts learning outcomes but also equips students with comprehensive critical thinking skills to face 21st-century challenges. This supports the assertion in the introduction that critical thinking is a core competence for 21st-century education [5], [6], [7].

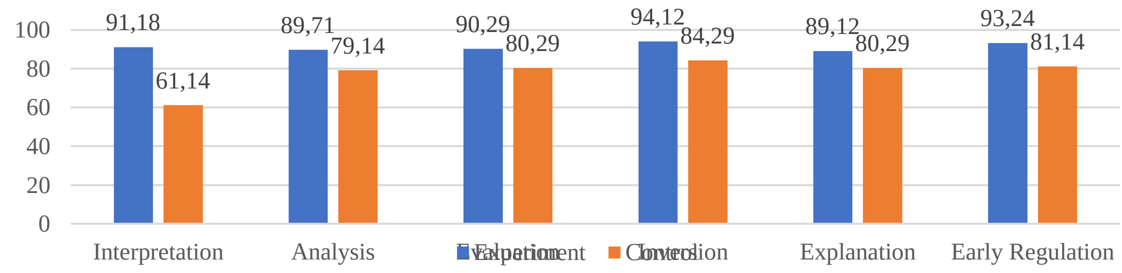

Figure 4. Attitude Scale for Each Critical Thinking Ability Indicator

Based on Figure 4, the students' attitudes toward critical thinking in the experimental class yielded very high results, with an inference score of 94.12%, self-regulation of 93.24%, interpretation of 91.18%, evaluation of 90.29%, analysis of 89.71%, and explanation of 89.12%. All scores fell within the "very good" category, confirming that students not only mastered the critical thinking process but also demonstrated a positive attitude toward its application in learning.

In the control class, the scores obtained were lower, with inference at 84.29%, self-regulation at 81.14%, interpretation at 81.14%, evaluation at 80.29%, explanation at 80.29%, and analysis at 79.14%. These results were only in the "good" to near "very good" category. These findings demonstrate that context-based inquiry learning not only enhances cognitive abilities but also cultivates positive dispositions and attitudes toward critical thinking, which are crucial in developing reflective, independent, and sustainable learners.

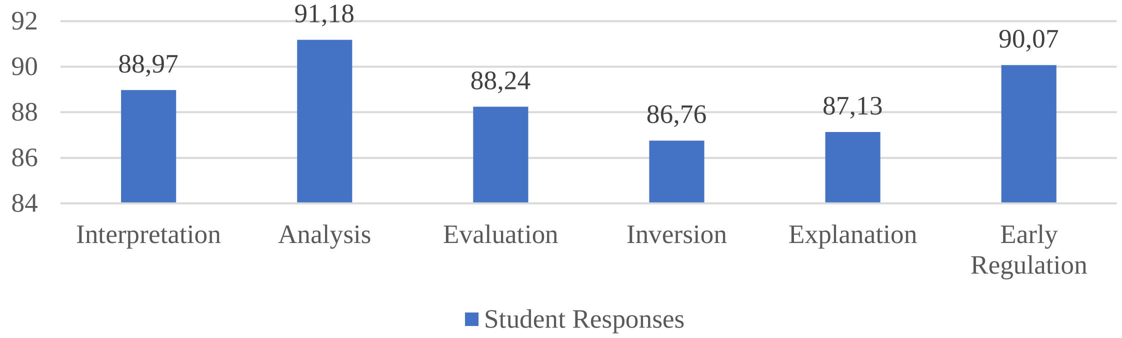

Figure 5. Student Responses for each Indicator

Based on the questionnaire results (Figure 5), the average student response to the implementation of context-based inquiry learning reached 88.73%, categorized as very good. The indicators with the highest scores were student assessments of the learning model (91.18%) and the model's relationship to the plant diversity material (90.07%). These results indicate that students considered this model effective, enjoyable, and helped them understand biological concepts more concretely Importantly, these findings align with previous studies [24], [28], providing further validation of the effectiveness of context-based and inquiry-based learning in enhancing conceptual understanding, providing further validation of the effectiveness of context-based and inquiry-based learning in enhancing conceptual understanding. This aligns with international practices where inquiry-based learning has been widely successful, such as in Finland and Canada [24], [25], [26], [27].

Other indicators included interest in the model (88.97%), increased critical thinking skills (88.24%), assessment of critical thinking development (86.76%), and interest in plant diversity (87.13%). These positive responses reflect that student’s felt more motivated, actively engaged, and aware of the development of their critical thinking skills. Overall, the results confirm that the implementation of context-based inquiry learning not only improves test scores but also strengthens students' affective aspects and participation in learning.

The study's results indicate that the application of Context-Based Inquiry Learning (CBIL) effectively enhances students' critical thinking skills. The t-test analysis revealed no significant difference in initial abilities (pretest) between the experimental and control classes. However, after treatment, a significant difference was found in the posttest, with an average of 87.57 for the experimental class, which was higher than 70.85 for the control class. This improvement was reinforced by the N-Gain analysis, which showed that the experimental class achieved a score of 0.80 (high category), while the control class achieved a score of 0.53 (medium category). These data indicate that CBIL can provide more optimal improvements compared to conventional learning.

Analysis of each critical thinking indicator also showed consistent improvement in the experimental class, including in interpretation, analysis, evaluation, inference, explanation, and self-regulation, all of which were higher than in the control class. These results confirm that CBIL effectively trains higher-order thinking skills comprehensively through a real-world context-based inquiry process. This improvement aligns with previous frameworks, which emphasise these six key aspects as the foundation of critical thinking [37], [39]. The attitude scale revealed that students in the experimental class had a highly positive attitude toward critical thinking, with scores on all indicators falling within the "very good" category (89–94%). In contrast, the control class only achieved the "good" to near-very good category. This difference suggests that CBIL not only affects cognitive abilities but also influences students' positive dispositions toward critical thinking. This positive attitude is important because it is a prerequisite for the formation of reflective, independent, and sustainable learners. The results of the student response questionnaire further strengthen previous findings. The average response rate reached 88.73%, categorised as very good, particularly for the model assessment indicators (91.18%) and the model's relationship to the plant diversity material (90.07%). Furthermore, students found the model interesting, enjoyable, and helpful in concretely understanding biological concepts. These findings confirm that CBIL not only improves academic achievement but also creates a more meaningful and contextual learning experience.

Overall, data triangulation showed consistent findings across three main aspects: (1) cognitive, through increased posttest and N-Gain scores; (2) affective, through students' positive attitudes toward critical thinking;

and (3) perceptual, through excellent responses to learning. The combination of these three aspects provides strong evidence that CBIL is a practical and relevant learning model for developing students' critical thinking skills, in line with previous research findings [24], [28], [31].

4. CONCLUSION

The findings of this study demonstrate that context-based inquiry learning significantly enhances students' critical thinking skills in plant diversity, with measurable improvement across all critical thinking indicators. Beyond confirming effectiveness, this study contributes to biology education theory by empirically supporting the integration of contextual learning and structured scientific inquiry as a mechanism for fostering higher-order cognitive development in biodiversity instruction—an area traditionally dominated by descriptive and memorization-based approaches. The indicator-level analysis further refines the theoretical understanding of how specific dimensions of critical thinking evolve within context-driven inquiry processes. In practice, the results provide a structured pedagogical model that biology teachers can use to design lessons that connect real-life contexts with analytical reasoning tasks, thereby promoting reflective, participatory, and argument-based learning environments. In terms of research advancement, this study extends CBIL scholarship by situating its application within plant diversity content and the Indonesian secondary education context, offering granular empirical evidence of its cognitive and affective impact. Future research is recommended to examine the long-term retention effects of CBIL, its applicability across different biology topics and grade levels, and its integration with digital or technology-enhanced learning environments. Further studies employing larger, more diverse samples, randomized experimental designs, and mixed-methods approaches would also strengthen the generalizability and explanatory depth of CBIL research. Collectively, these contributions position context-based inquiry learning not merely as an alternative instructional strategy, but as a theoretically grounded and practically actionable approach to strengthening 21st-century thinking skills in science classrooms.

5. ACKNOWLEDGEMENT

Future research could expand the application of the context-based inquiry learning model to higher and lower levels of education, as well as to subjects other than biology, to assess the model's consistent effectiveness in developing critical thinking skills. Furthermore, integrating context-based inquiry learning with digital media or a project-based approach could be further explored as a strategy to encourage increased student motivation and active participation in the learning process.

6. REFERENCES

[1] H. A. Alismail and P. McGuire, "21st Century Standards and Curriculum: Current Research and Practice," *J. Educ. Pract.*, vol. Vol.6, No., no. ISSN 2222-1735, pp. 150–154, 2015.

[2] I. Fathurohman, M. F. Amri, A. Septiyanto, and Riandi, "Integrating STEM based Education for Sustainable Development (ESD) to Promote Quality Education: A Systematic Literature Review," *J. Penelit. Pendidik. IPA*, vol. 9, no. 11, pp. 1052–1059, 2023, doi: 10.29303/jppipa.v9i11.4430.

[3] C. Marouli, "Sustainability education for the future? Challenges and implications for education and pedagogy in the 21st century," *Sustain.*, vol. 13, no. 5, pp. 1–15, 2021, doi: 10.3390/su13052901.

[4] OECD, *Pisa 2022*, vol. 46, no. 183. 2024. doi: 10.22201/iisue.24486167e.2024.183.61714.

5] L. Favero, J. A. Pérez-Ortiz, T. Käser, and N. Oliver, "Enhancing Critical Thinking in Education by Means of a Socratic Chatbot," pp. 17–32, 2025, doi: 10.1007/978-3-031-93409-4_2.

[6] C. Gonsalves, "Generative AI's Impact on Critical Thinking: Revisiting Bloom's Taxonomy," *J. Mark. Educ.*, 2024, doi: 10.1177/02734753241305980.

[7] D. L. Jaramillo Gómez, A. J. Álvarez Maestre, A. E. Parada Trujillo, C. A. Pérez Fuentes, D. H. Bedoya Ortiz, and R. K. Sanabria Alarcón, "Determining Factors for the Development of Critical Thinking in Higher Education," *J. Intell.*, vol. 13, no. 6, pp. 1–22, 2025, doi: 10.3390/jintelligence13060059.

[8] K. Kleemola, H. Hyytinen, and A. Toom, "Exploring internal structure of a performance-based critical thinking assessment for new students in higher education," *Assess. Eval. High. Educ.*, vol. 47, no. 4, pp. 556–569, 2022, doi: 10.1080/02602938.2021.1946482.

[9] J. Miranda *et al.*, "The core components of education 4.0 in higher education: Three case studies in

engineering education," *Comput. Electr. Eng.*, vol. 93, no. June, 2021, doi: 10.1016/j.compeleceng.2021.107278.

[10] D. H. Wason, "The troublesome nature of learning to teach critical thinking: Using threshold concepts theory to support teacher education," *Think. Ski. Creat.*, vol. 55, no. October 2024, 2025, doi: 10.1016/j.tsc.2024.101661.

[11] X. Zeng and L. Ravindran, "Design, implementation, and evaluation of peer feedback to develop students' critical thinking: A systematic review from 2010 to 2023," *Think. Ski. Creat.*, vol. 55, no. November 2024, p. 101691, 2025, doi: 10.1016/j.tsc.2024.101691.

[12] C. Dawson, H. Julku, M. Pihlajamäki, J. K. Kaakinen, J. W. Schooler, and J. Simola, "Evidence-based scientific thinking and decision-making in everyday life," *Cogn. Res. Princ. Implic.*, vol. 9, no. 1, 2024, doi: 10.1186/s41235-024-00578-2.

[13] M. Vendrell-Morancho and A. V. Moya, "Mapping critical thinking: key contributions for rethinking education*," *Educ. e Pesqui.*, vol. 51, pp. 0–2, 2025, doi: 10.1590/S1678-4634202551278119en.

[14] M. H. Guamanga, C. Saiz, S. F. Rivas, and P. M. Bueno, "Critical Thinking and Metacognition: Pathways to Empathy and Psychological Well-Being," *J. Intell.*, vol. 13, no. 3, pp. 1–17, 2025, doi: 10.3390/jintelligence13030034.

[15] OCDE, *Resultados de PISA 2022 (Volumen I): El estado del aprendizaje y la equidad en la educación.*, vol. 1. 2023.

[16] D. S. Setiana, R. Y. Purwoko, and Sugiman, "The application of mathematics learning model to stimulate mathematical critical thinking skills of senior high school students," *Eur. J. Educ. Res.*, vol. 10, no. 1, pp. 509–523, 2021, doi: 10.12973/EU-JER.10.1.509.

[17] T. Demircioglu, M. Karakus, and S. Ucar, *Developing Students' Critical Thinking Skills and Argumentation Abilities Through Augmented Reality–Based Argumentation Activities in Science Classes*, vol. 32, no. 4. Springer Netherlands, 2023. doi: 10.1007/s11191-022-00369-5.

[18] Y. Li, "A Study on University Students' Participation in College Ideological and Political Education from the Perspective of the 'Big Ideological and Political Course,'" *Int. Educ. Res.*, vol. 8, no. 2, p. p117, 2025, doi: 10.30560/ier.v8n2p117.

[19] I. M. A. Rajamuddin, A. Arbi, and S. Syafiah, "Critical Education in Secondary School: Power Relations and National Identity Formation in Secondary Schools," *Scaffolding J. Pendidik. Islam dan Multikulturalisme*, vol. 7, no. 1, pp. 626–644, 2025, doi: 10.37680/scaffolding.v7i1.7228.

[20] M. A. Muttaqo and D. Erawati, "Emancipatory Qur ' anic Hadith Education in the Digital Age : A Critical Analysis of Learning Models in MTsN 1 Palangka Raya," vol. 8, no. 2, pp. 688–700, 2025.

[21] I. Sasson, I. Yehuda, S. Miedijensky, and N. Malkinson, "Designing new learning environments: An innovative pedagogical perspective," *Curric. J.*, vol. 33, no. 1, pp. 61–81, 2022, doi: 10.1002/curj.125.

[22] L. Darling-Hammond, A. C. W. Schachner, S. K. Wojcikiewicz, and L. Flook, "Educating teachers to enact the science of learning and development," *Appl. Dev. Sci.*, vol. 28, no. 1, pp. 1–21, 2024, doi: 10.1080/10888691.2022.2130506.

[23] T. C. Ramos, F. C. Silva, and P. C. C. Mendonça, *Epistemic Practices Created by Discursive Interactions between Pre-service Chemistry Teachers*, no. 0123456789. Springer Netherlands, 2025. doi: 10.1007/s11191-025-00661-0.

[24] M. Amin, Y. Rahmawati, A. Sudrajat, and A. Mardiah, "Enhancing Primary School Students' Critical Thinking Skills through the Integration of Inquiry-Based STEM Approach on Teaching Electricity in Science Learning," *J. Phys. Conf. Ser.*, vol. 2377, no. 1, 2022, doi: 10.1088/1742-6596/2377/1/012090.

[25] A. L. Simanjuntak, N. Hermita, and Z. H. Putra, "Application of Inquiry Learning Model Assisted

Interactive Media on Material Shape and Energy Change to Improve Critical Thinking Skills of Elementary School Students," *AL-ISHLAH J. Pendidik.*, vol. 14, no. 4, pp. 7303–7318, 2022, doi: 10.35445/alishlah.v14i4.2054.

[26] J. Herranen, P. Kousa, E. Fooladi, and M. Aksela, "Inquiry as a context-based practice–a case study of pre-service teachers' beliefs and implementation of inquiry in context-based science teaching," *Int. J. Sci. Educ.*, vol. 41, no. 14, pp. 1977–1998, 2019, doi: 10.1080/09500693.2019.1655679.

[27] N. Intan Maharani, W. Dasna, and C. Utama, "MADRASAH: Jurnal Pendidikan dan Pembelajaran Dasar The Effectiveness of Inquiry-Based Learning Instrument to Enhance Student's Critical Thinking Skills," *MADRASAH J. Pendidik. dan Pembelajaran Dasar*, vol. 15, no. 02, pp. 66–77, 2023, [Online]. Available: http://ejournal.uin-malang.ac.id/index.php/madrasah/indexhttp://ejournal.uin-malang.ac.id/index.php/madrasah/index

[28] Z. Arifin, Sukarmin, S. Saputro, and A. Kamari, "The effect of inquiry-based learning on students' critical thinking skills in science education: A systematic review and meta-analysis," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 21, no. 3, 2025, doi: 10.29333/ejmste/15988.

[29] G. T. Pawilen, "Designing Instruction through Context-based Inquiry Learning (CBIL) Model," no. August, pp. 114–124, 2024, [Online]. Available: https://www.researchgate.net/publication/383119283.

[30] L. Zhang and Y. Ma, "A study of the impact of project-based learning on student learning effects: a meta-analysis study," *Front. Psychol.*, vol. 14, no. July, pp. 1–14, 2023, doi: 10.3389/fpsyg.2023.1202728.

[31] I. D. Pursitasari, E. Suhardi, A. P. Putra, and I. Rachman, "Enhancement of student's critical thinking skill through science context-based inquiry learning," *J. Pendidik. IPA Indones.*, vol. 9, no. 1, pp. 97–105, 2020, doi: 10.15294/jpii.v9i1.21884.

[32] L. Yu and Z. M. Zin, "The critical thinking-oriented adaptations of problem-based learning models: a systematic review," *Front. Educ.*, vol. 8, 2023, doi: 10.3389/feduc.2023.1139987.

[33] C. Cort, M. Nussbaum, J. Harcha, D. Alvares, and L. Felipe, "Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID- 19 . The COVID-19 resource centre is hosted on Elsevier Connect , the company ' s public news and information ," no. January, 2020.

[34] I. K. A. S. Andi Suryawan, I Gede Astawan, and Gusti Ayu Putu Sukma Trisna, "Enhancing Critical Thinking and Creativity: The Impact of Tri Kaya Parisudha-Based Metaphorical Thinking in Elementary Education," *Think. Ski. Creat. J.*, vol. 7, no. 2, pp. 247–257, 2024, doi: 10.23887/tscj.v7i2.92994.

[35] B. Sitotaw Goshu and M. Ridwan, "Exploring the Role of Project-Based Learning in Fostering Critical Thinking Skills," *Britain Int. Linguist. Arts Educ. Sci. J.*, vol. 6, no. 3, pp. 149–166, 2024, doi: 10.33258/biolae.v6i3.1201.

[36] D. Cahyono, "THE ROLE OF THE TEACHER AS A FACILITATOR IN THE LEARNING PROCESS: A REVIEW OF EDUCATIONAL PSYCHOLOGY," *Int. J. Teach. Learn.*, vol. 3, no. 1, p. 205~212.

[37] S. Zubaidah, "Berfikir Kritis : Kemampuan Berpikir Tingkat Tinggi Yang dapat Dikembangkan Melalui Pembelajaran Sains," *Semin. Nas. Sains*, vol. 6, no. 8, pp. 1–14, 2016, [Online]. Available: https://www.researchgate.net/profile/Siti-Zubaidah-7/publication/318040409_Berpikir_Kritis_Kemampuan_Berpikir_Tingkat_Tinggi_yang_Dapat_Dikembangkan_melalui_Pembelajaran_Sains/links/59564c650f7e9b591cda994b/Berpikir-Kritis-Kemampuan-Berpikir-Tingkat-Tingg

[38] R. Rattanachaithada, P. Kwangmuang, P. Vongtathum, R. Gamlunglert, and S. Srikoon, "A confirmatory factor analysis of scientific critical thinking in secondary school," *Cogent Educ.*, vol. 12, no. 1, p., 2025, doi: 10.1080/2331186X.2025.2467508.

[39] A. García-Carmona, "Scientific Thinking and Critical Thinking in Science Education : Two Distinct but Symbiotically Related Intellectual Processes," *Sci. Educ.*, vol. 34, no. 1, pp. 227–245, 2025, doi:

10.1007/s11191-023-00460-5.

[40] J. Siantuba, L. Nkhata, and T. de Jong, "The impact of an online inquiry-based learning environment addressing misconceptions on students' performance," *Smart Learn. Environ.*, vol. 10, no. 1, 2023, doi: 10.1186/s40561-023-00236-y.

[41] M. Tindangen, "Inquiry-Based Learning Model to Improve Higher Order Thinking Skills," *Asian Soc. Sci.*, vol. 14, no. 7, p. 39, 2018, doi: 10.5539/ass.v14n7p39.

[42] N. Frank, W., "Research Methodology," *Writ. J.*, vol. 2, no. 1, pp. 1–13, 2012.

[43] M. Waruwu, S. N. Pu`at, P. R. Utami, E. Yanti, and M. Rusydiana, "Metode Penelitian Kuantitatif: Konsep, Jenis, Tahapan dan Kelebihan," *J. Ilm. Profesi Pendidik.*, vol. 10, no. 1, pp. 917–932, 2025, doi: 10.29303/jipp.v10i1.3057.

[44] C. Martinez, "Developing 21st century teaching skills: A case study of teaching and learning through project-based curriculum," *Cogent Educ.*, vol. 9, no. 1, 2022, doi: 10.1080/2331186X.2021.2024936.