JPII 13 (3) (2024) 367-376

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

THE IMPACT OF INQUIRY-BASED LEARNING ON STUDENTS' CRITICAL THINKING IN BIOLOGY EDUCATION PROGRAMS WITHIN OPEN AND DISTANCE LEARNING SYSTEMS

A. Sapriati*[1], U. Rahayu[2], I. Sausan[3], M. Sekarwinahyu[2], R. S. Anam[1]

[1]Magister Program in Basic Education, Universitas Terbuka, Indonesia
[2]Biology Education Program, Universitas Terbuka, Indonesia
[3]Chemistry Education Program, Universitas Terbuka, Indonesia

DOI: 10.15294/jpii.v13i3.5789

Accepted: July 20th, 2024. Approved: August 28th, 2024. Published: August 28th 2024

ABSTRACT

This study examines the impact of Inquiry-Based Learning (IBL) on enhancing critical thinking skills in an open and distance learning (ODL) environment, focusing on a biology education program. The research employed a pre-experimental one-group posttest-only design with 35 students participating in online sessions. These sessions involved formulating questions, designing experiments, conducting observations, and analyzing data. Quantitative analysis using percentages, means, standard deviations, and regression revealed that over 75% of students achieved very good performance in key areas like formulating hypotheses and designing experiments. The regression analysis confirmed that IBL significantly affected critical thinking skills ($R^2 = 0.849$; $p = 0.05$). The study concludes that a systematic learning design that encourages active learning and provides continuous feedback is crucial for developing critical thinking skills in ODL settings. These findings provide insights for curriculum developers and educators to optimize IBL implementation, thereby enhancing educational outcomes and fostering independent learning in distance education environments. Further research is suggested to refine this approach and ensure deeper understanding and application of scientific principles.

Keywords: biology; critical thinking; inquiry-based learning; open and distance learning

INTRODUCTION

In the rapidly evolving landscape of education, developing critical thinking skills is a paramount goal for preparing students to navigate complex biological concepts, solve real-world problems, and make informed decisions (Killpack et al., 2020; Taghinezhad & Riasati, 2020; Loy et al., 2022; Coyte, 2023; Cossu et al., 2024; Song et al., 2024). Critical thinking involves the ability to analyze arguments, identify biases, evaluate evidence, and draw reasoned conclusions. These skills are essential for students in biology, where understanding intricate systems and making data-driven decisions are crucial (Amin et al., 2020; Killpack et al., 2020; McFadden & Fuselier, 2020; Sadeghi et al., 2020; Spence et al., 2020; Kreher et al., 2021; Aston, 2023; McKee et al., 2023). Traditional teaching methods have often fallen short in fostering these essential skills, particularly within the constraints of open and distance learning (ODL) environments.

The shift towards ODL systems necessitates innovative pedagogical strategies that can effectively engage students and enhance their critical thinking abilities (Rahayu & Sapriati, 2018; Chusni et al., 2020; Pursitasari et al., 2020; Cortázar et al., 2021; Garrison, 2022; Tomesko et al., 2022; Bekteshi et al., 2023; Al-Haddad et al., 2024; Pereles et al., 2024; Santos-Díaz et al., 2024). Inquiry-Based Learning (IBL) presents a promising approach, emphasizing student-driven

***Correspondence Address**
E-mail: lia@ecampus.ut.ac.id

inquiry and problem-solving to enhance critical thinking, especially in biology education where analytical and evaluative skills are crucial (Gómez & Suárez, 2020; Martín-Gámez et al., 2020; Mitarlis et al., 2020; Liu et al., 2021; Irwanto, 2023; Nzomo et al., 2023; Muhamad Dah et al., 2024; Rahayu et al., 2024).

Empirical evidence underscores the effectiveness of IBL in enhancing various skills across various educational contexts (Costes-Onishi et al., 2020; Fatmawati & Rustaman, 2020; Abaniel, 2021; Ganajová et al., 2021; irado-Olivares et al., 2021; Öztürk et al., 2022; T Chu et al., 2023; de Jong et al., 2023; Hsu et al., 2024;). A meta-analysis confirmed that IBL significantly improves learning outcomes, including critical thinking and problem-solving skills (Duran & Dökme, 2016; Jerrim et al., 2019; Gómez & Suárez, 2020; otiriou et al., 2020; Wu et al., 2021; Öztürk et al., 2022; SCoyte, 2023). For example, students engaged in IBL are better at formulating research questions, designing and conducting experiments, and analyzing data systematically (Spence et al., 2020; Killpack et al., 2020; Doucette et al., 2021; Kreher et al., 2021; McKee et al., 2023; Li et al., 2024). These skills are crucial for understanding complex biological systems and applying theoretical knowledge to practical problems (Gómez & Suárez, 2020; Killpack et al., 2020; Lameras et al., 2021; McKee et al., 2023). Furthermore, integrating digital tools with IBL increases student motivation and engagement, making science education more accessible and effective in ODL systems (Liu et al., 2021; Pereles et al., 2024). These findings highlight the potential of IBL to transform biology education, particularly within ODL frameworks, by providing a robust structure for active learning and continuous feedback (Chusni et al., 2020; Sotiriou et al., 2020; Ahmadi et al., 2023; Coyte, 2023).

Pursitasari et al. (2020) and Wale & Bishaw, (2020) found that IBL significantly enhances students' critical thinking by engaging them in activities that require questioning, experimenting, and reflecting on their learning processes. Killpack et al. (2020) and Liu et al. (2021) demonstrated that the use of IBL in biology education improves students' understanding and abilities. Additionally, previous researhers highlighted that structured inquiry tasks in biology significantly boost students' performance in various cognitive domains, including formulating hypotheses, designing experiments, and analyzing data (Fatmawati & Rustaman, 2020; Killpack et al., 2020; Spence et al., 2020 Kreher et al., 2021; Chu et al., 2023; Coyte, 2023; McKee et al., 2023; Hsu et al., 2024; Li et al., 2024).

Despite the demonstrated benefits of IBL, significant gaps remain in the literature, particularly concerning its application in ODL settings. Most existing research has focused on traditional classroom environments, with limited studies examining the impact of IBL on biology learning in ODL systems (Killpack et al., 2020; Liu et al., 2021). While various studies have demonstrated the positive impact of IBL on student performance, such as engagement and critical thinking, there is a lack of comprehensive research specifically addressing its efficacy in biology education within ODL contexts (Bekteshi et al., 2023; Chu et al., 2023). Furthermore, while teacher and student acceptance of IBL has been explored, there is still a need for in-depth studies on the practical challenges and strategies for implementing IBL in ODL environments (Coyte, 2023; Hsu et al., 2024). Addressing these gaps is crucial for developing effective educational practices that enhance critical thinking and biology learning outcomes in ODL systems. For instance, Bekteshi et al. (2023), Pereles et al. (2024) and Tomesko et al. (2022) emphasize the necessity for innovative strategies to adapt IBL for ODL environments, highlighting the need for empirical studies to validate these approaches. Coyte, 2023point-out that while the theoretical benefits of IBL are well-documented, its practical implementation in ODL settings remains under-researched. Additionally, research on enhancing 21st-century skills through IBL highlights the need for innovative strategies to adapt IBL for ODL learning management (Bekteshi et al., 2023; Coyte, 2023).

This study aims to investigate the impact of Inquiry-Based Learning (IBL) on the development of critical thinking skills in students enrolled in a biology education program within an open and distance learning (ODL) system. While this research aims to explore the impact of IBL on critical thinking skills, several limitations must be acknowledged. First, the study focuses specifically on a biology education program, which may limit the generalizability of the findings to other disciplines. Second, the research is conducted within the context of an ODL system, which may not fully capture the dynamics present in traditional classrooms. Third, the study is limited to a specific educational institution, which may influence the applicability of the results to other contexts.

METHODS

This research utilized an experimental one-group posttest-only design (Johnson & Christensen, 2014; Kumar, 2011) examining the development of inquiry-based learning (IBL) and its influence on students' critical thinking skills in a Natural Resources and Environmental Conservation course. The course was conducted within a biology education program utilizing an open and distance learning system in Indonesia. The pilot project included 35 students—24 women and 11 men—who participated in eight online tutorial sessions aimed at enhancing their IBL and critical thinking skills.

The research commenced with a comprehensive planning and preparation stage. The objective was to design and prepare the IBL activities and materials. This involved conducting an extensive review of the literature on IBL and critical thinking in biology education to develop relevant and effective activities. Detailed lesson plans, instructional materials, and assessment rubrics were created based on the findings from the literature review and consultations with experts.

The next stage involved the implementation of the IBL program. During this stage, students engaged in various activities including formulating research questions, designing and conducting experiments, documenting observations, analyzing data, and synthesizing their findings into comprehensive formats such as videos, reports, or presentations. Reflective sessions were integrated into the program to allow students to assess the strengths and weaknesses of their experiments. The implementation was conducted entirely online, utilizing a Learning Management System (LMS) to facilitate and monitor student engagement.

Monitoring and assessment were crucial components of this research. Throughout the IBL activities, students' engagement and skill development were closely monitored using the LMS. Tutors evaluated student discussions and assignments using detailed rubrics designed for IBL and critical thinking assessments. These rubrics included indicators for various skills such as formulating hypotheses, designing experiments, conducting observations, analyzing data, and reflecting on the process (see Tables 1 and 2). The evaluation process aimed to gauge the effectiveness of the IBL approach in enhancing critical thinking and conceptual understanding.

Table 1. Indicator and Rubrics of IBL

Indicators	Assessment Rubrics
Indicator 1: Formulating questions/ hypotheses	The statements are pertinent, aligned with the research scope, significant, feasible, and consistent with the researcher's domain expertise.
Indicator 2: Designing experiments	The experimental design is relevant to the research question and hypothesis, encompassing all necessary equipment, materials, and procedures.
Indicator 3: Conducting experiment/observation	Demonstrates proficiency in conducting experiments, observing systematically and accurately, and collecting data efficiently.
Indicator 4: Analyzing data	Data analysis involves the capability to process, analyze, and interpret the collected data effectively.
Indicator 5: Concluding and writing a full report	Draws conclusions, presents findings/results clearly, and utilizes appropriate scientific references.
Indicator 6: Performing reflections	Reflection entails evaluating methodologies, critiquing the processes used, assessing strengths and weaknesses, and developing improvement plans.

The final stage of the research involved data analysis. The data collected from student assessments were analyzed to determine the impact of the IBL program on critical thinking skills. Descriptive statistics, including percentages, means, and standard deviations, were calculated to summarize the data. Inferential statistics, specifically regression analysis, were performed to examine the relationship between participation in the IBL program and improvements in critical thinking skills. Table 2 shows indicator and rubrics of critical thinking skills

Table 2. Indicator and Rubrics of Critical Thinking Skills

Indicators	Assessment Rubrics
Indicator 1. Analyzing arguments	Analyze and evaluate arguments in various formats, incorporating complex case studies.
Indicator 2. Observing and considering observations	Systematically observe, record, and reflect on observations on a regular basis.
Indicator 3. Defining terms and considering definitions	Formulate key defini-tions and support them with relevant examples.
Indicator 4. Make decisions and consider the results.	Make informed deci-sions based on avail-able information and conduct thorough analysis of the results.
Indicator 5. Deciding on a course of action	Plan, execute, evaluate self-initiated projects, and develop compre-hensive improvement plans.

The statistical analysis was conducted using software such as SPSS or R, following guidelines from established methods (Tabachnick & Fidell, 2013; Meyer et al., 2023; Field, 2024).

The research instruments used in this study included assessment rubrics for both IBL and critical thinking skills. The IBL assessment focused on six key indicators: formulating questions/hypotheses, designing experiments, conducting experiments/observations, analyzing data, concluding and writing a full report, and performing reflections. Tutors used these rubrics to score student performance, categorizing the results into five criteria: very good, good, sufficient, poor, and very poor (see Table 3). Similarly, the critical thinking assessment included five indicators: analyzing arguments, observing and considering observations, defining terms and considering definitions, making decisions and considering the results, and deciding on a course of action. These rubrics were used to evaluate student discussions and assignments, ensuring a comprehensive assessment of their critical thinking abilities.

Table 3. Criteria for Inquiry and Critical Thinking

No	Score	Criteria
1	80-100	Very Good
2	70-79	Good
3	60-69	Enough
4	40-59	Less
5	30-39	Very Less

To enhance the research stages and methodologies, modifications were made based on sources referred to by the researcher. These modifications included the incorporation of additional reflective activities, the use of more interactive and collaborative online tools, and the integration of peer feedback mechanisms to further support student engagement and learning. These modifications aimed to address challenges identified in previous studies, such as learner isolation and inadequate feedback in ODL settings (Tomesko et al., 2022; Bekteshi et al., 2023; Pereles et al., 2024).

RESULTS AND DISCUSSION

The assessment of Inquiry-Based Learning (IBL) revealed varying levels of proficiency across different stages of the inquiry process. This suggests that students excelled in planning and structuring their experiments, which is a crucial skill in scientific inquiry. These findings highlight areas where students require further development, particularly in data analysis and experiment conduction, as illustrated in Figure 1.

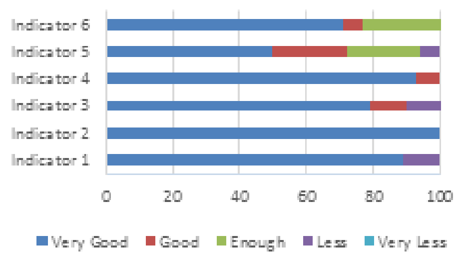

Figure 1. Performance of Skills in IBL

In examining students' critical thinking skills, the research revealed significant findings. Predominantly, students exhibited performance across all tasks, which underscores their ability to engage deeply with the material and think critically. This suggests that while students are generally proficient in critical thinking, there are specific areas, particularly in observation and analysis, that need enhancement, as shown in Figure 2.

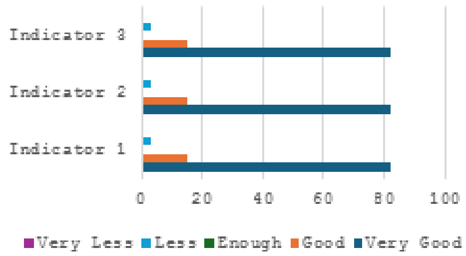

Figure 2. Performance of Critical Thinking Skills

The quantitative descriptive analysis of six student skills in inquiry learning showed diverse levels of performance. The findings indicated that the highest average performance was in analyzing data, with indicators of designing experiments also showing high proficiency and consistency among students. Indicators of formulating questions and hypotheses demonstrated strong mean performance, indicating general proficiency among students. The skills of conducting experiments, observing, and reflecting showed moderate to good performance but with some variability. The indicator of performing reflections had the highest standard deviation, suggesting varied proficiency levels among students. Concluding and creating a report had the lowest mean score, indicating challenges in this area for many participants. Table 4 provides detailed data on the performance of IBL skills.

Table 4. Data on the Results of IBL Skills Performance

Inquiry Learning Skills	Mean	Std. Dev
Indicator 1 (N = 26)	91.5385	11.81264
Indicator 2 (N = 33)	94.9697	4.33362
Indicator 3 (N = 19)	90.7368	13.39918
Indicator 4 (N = 15)	96.9333	7.95044
Indicator 5 (N = 18)	78.3333	15.71810
Indicator 6 (N = 17)	86.6471	17.31669

Similarly, the analysis of critical thinking skills revealed a high mean score, indicating strong performance in this area. The skills assessed included analyzing arguments, observing and considering observations, defining terms, making decisions, and deciding on a course of action. The low standard deviation suggested consistent performance among students, with few outliers. Table 5 presents detailed data on critical thinking skills performance.

Table 5. Data on the Results of Critical Thinking

Critical Thinking Skills	Mean	Std. Deviation
Indicator 1 (N =34)	86.2647	9.00272
Indicator 2 (N =34)	82.2857	8.48380
Indicator 3 (N =34)	86.2647	9.00272

An analysis of students' understanding of ecosystem topics, including the interactions between biotic and abiotic components, indicated varied levels of proficiency (see Figure 3). The distribution of level of understanding suggests that the majority of students have a satisfactory to very good understanding of the topic, with only a minor fraction performing poorly.

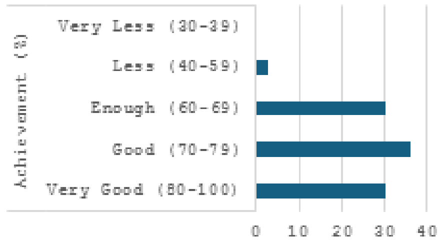

Figure 3. Students' Understanding of Content

A regression model was applied to explore the relationship between IBL skills and critical thinking performance. The model included several predictors from the IBL indicators and a dependent variable representing critical thinking skills. The model summary displayed a very strong correlation (R value) and a significant proportion of variance explained by the model (R Square). The adjusted R Square, which accounts for the number of predictors, was slightly lower but still indicated a good model fit. The significance level (Sig. F Change) was 0.005, indicating that the predictors significantly improved the model. The Durbin-Watson statistic suggested no significant autocorrelation in the residuals, confirming the model's reliability. The ANOVA results further confirmed the model's significance, with a high F-statistic and a significance level of 0.005, reinforcing that the model is statistically significant. The findings demonstrated that effective inquiry discussions significantly enhance critical thinking performance.

Table 6. Relationship Between Critical Thinking and Inquiry Learning Skills in the Task

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.921[a]	0.849	0.763	6.00472	0.849	9.849	4	7	0.005	1.850

a. Predictors: (Constant), Discussion 8, Discussion 7, Discussion 6, Discussion 2
b. Dependent Variable: Task

ANOVA[a]

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1420.520	4	355.130	9.849	.005[b]
	Residual	252.397	7	36.057		
	Total	1672.917	11			

a. Dependent Variable: Assignment
b. Predictors: (Constant), Discussion 8, Discussion 7, Discussion 6, Discussion 2

The application of IBL in teaching ecosystem topics within biology education enhances understanding and engagement with biological concepts (Killpack et al., 2020; Taghinezhad & Riasati, 2020; Loy et al., 2022; Coyte, 2023; Cossu et al., 2024; Song et al., 2024). IBL encourages students to ask questions, design experiments, and analyze results, fostering creativity and innovation (Gómez & Suárez, 2020; Martín-Gámez et al., 2020; Mitarlis et al., 2020; Liu et al., 2021; Nzomo et al., 2023; Irwanto, 2023; Muhamad Dah et al., 2024; Rahayu et al., 2024) . It prepared students to tackle complex biological problems, contributing to advances in biological research and education (Gómez & Suárez, 2020; Killpack et al., 2020; Lameras et al., 2021; McKee et al., 2023). Emphasizing student-led investigations and active learning makes biology education more dynamic and effective (Gómez & Suárez, 2020; Killpack et al., 2020; Lameras et al., 2021; McKee et al., 2023).

The findings from this study indicate that while students show proficiency in designing and conducting experiments and formulating research questions, there is a need for improvement in data analysis and presentation. Structured guidance and feedback through online platforms can enhance these skills (Chusni et al., 2020; Sotiriou et al., 2020; Ahmadi et al., 2023; Coyte, 2023). Future IBL programs should focus on enhancing analytical and communication skills and providing comprehensive guidance on reflection processes to deepen research understanding (Fatmawati & Rustaman, 2020; Killpack et al., 2020; Spence et al., 2020; Doucette et al., 2021; Kreher et al., 2021; McKee et al., 2023; Li et al., 2024). Sharing these results supports the educational community in understanding how students acquire inquiry skills and the challenges they face, contributing to the development of best practices (Gómez & Suárez, 2020; Martín-Gámez et al., 2020; Mitarlis et al., 2020; Liu et al., 2021; Irwanto, 2023; Muhamad Dah et al., 2024).

Furthermore, the results showed a strong link between inquiry discussion skills and critical thinking task performance, indicating that effective inquiry can significantly enhance critical thinking (Duran & Dökme, 2016; Jerrim et al., 2019; Gómez & Suárez, 2020; Sotiriou et al., 2020; Wu et al., 2021; Öztürk et al., 2022; Coyte, 2023). Focusing on these strategies can help develop essential skills in students (Costes-Onishi et al., 2020; Fatmawati & Rustaman, 2020; Ganajová et al., 2021; Abaniel, 2021; Tirado-Olivares et al., 2021; Tirado-Olivares et al., 2021 Öztürk et al., 2022; Chu et al., 2023; de Jong et al., 2023; Hsu et al., 2024). Future directions for IBL include providing more support in critical thinking, especially in decision-making and evaluation, and incorporating hands-on exercises like case studies and project-based learning (Fatmawati & Rustaman, 2020; Killpack et al., 2020; Spence et al., 2020; Kreher et al., 2021; Chu et al., 2023; Coyte, 2023; McKee et al., 2023; Hsu et al., 2024; Li et al., 2024). Structured feedback and opportunities for reflection can further sharpen decision-making abilities (Chusni et al., 2020; Sotiriou et al., 2020; Coyte, 2023). Revisiting the learning design to emphasize decision-making and outcomes can improve educational effectiveness (Gómez & Suárez, 2020; Killpack et al., 2020; Lameras et al., 2021; McKee et al., 2023).

Critical thinking skills developed through studying ecosystem topics in biology education significantly enhance learning success in other biology courses (Killpack et al., 2020; Pursitasari et al., 2020; Wale & Bishaw, 2020; Liu et al., 2021). These skills enable rigorous analysis and evaluation of complex biological concepts, leading to deeper understanding (Gómez & Suárez, 2020; Killpack et al., 2020; Lameras et al., 2021; McKee et al., 2023). Critical thinking also fosters independent learning and resilience, aiding students in adapting and excelling in various academic contexts (Gómez & Suárez, 2020; Killpack et al., 2020; Lameras et al., 2021; McKee et al., 2023). Integrating critical thinking in ecosystem studies promotes a holistic understanding of biology, encouraging connections between ecological principles and other biology areas, thus enriching the overall educational experience (Costes-Onishi et al., 2020; Fatmawati & Rustaman, 2020; Ganajová et al., 2021; Tirado-Olivares et al., 2021; Öztürk et al., 2022; Chu et al., 2023; de Jong et al., 2023; Hsu et al., 2024).

The research significantly contributes to biology courses in open and distance learning (ODL) systems by providing evidence of the effectiveness of Inquiry-Based Learning (IBL) in enhancing critical thinking and inquiry skills. The study highlights the potential of IBL to create more interactive and engaging learning experiences, which is crucial for ODL where student engagement can be a challenge. By incorporating IBL, educators can facilitate active learning and deeper understanding of biological concepts, addressing the common issues of learner isolation and passive reception of information typical in ODL (Fatmawati & Rustaman, 2020; Killpack et al., 2020; Spence et al., 2020; Kreher et al., 2021; Chu et al., 2023; Coyte, 2023; McKee et al., 2023; Hsu et al., 2024; Li et al., 2024).

In the context of distance education, IBL provides a robust framework for engaging students and ensuring active participation despite physical separation (Tomesko et al., 2022; Bekteshi et al., 2023; Pereles et al., 2024). IBL encourages the use of digital tools and online platforms for conducting experiments, sharing findings, and collaborating with peers, making learning more interactive and engaging (Cortázar et al., 2021; Liu et al., 2021; Tomesko et al., 2022; Bekteshi et al., 2023; Pereles et al., 2024). This approach helps mitigate some of the challenges of distance education, such as isolation and lack of immediate feedback, by fostering a sense of community and ongoing interaction. By developing critical thinking skills through IBL, students in a distance education system become more self-sufficient and capable of managing their learning independently, leading to better educational outcomes.

The findings on the effectiveness of inquiry-based learning (IBL) significantly contribute to the field of biology education. The research demonstrates that IBL not only enhances student engagement and understanding of biological concepts but also fosters critical skills such as creativity, problem-solving, and communication. By promoting active learning and deeper comprehension, IBL helps develop critical thinking skills essential for tackling complex biological challenges. Moreover, this study offers refined teaching strategies aimed at improving learning outcomes and better preparing students for advanced studies. The research also highlights the versatility of IBL across different educational settings, including traditional and open distance learning environments, and provides a comprehensive framework for its implementation to maximize learning effectiveness. The versatility of the IBL and its comprehensive framework are the novelties offered by this research. By identifying specific areas where students may need further development, such as data analysis and presentation, the study offers targeted solutions for curriculum design and instructional strategies. The positive impact of IBL on student outcomes suggests its potential to transform biology education by fostering independent thinking and preparing students for future scientific endeavors.

CONCLUSION

This study demonstrated that Inquiry-Based Learning (IBL) significantly enhances critical thinking and inquiry skills in a biology education program within an open and distance learning (ODL) system. Students excelled in designing experiments but needed improvement in data analysis and reporting. The regression analysis confirmed a strong correlation between effective inquiry discussions and critical thinking performance. The findings underscore the need for structured guidance, immediate feedback, and the integration of interactive tools to support student engagement and skill development in ODL. For effective implementation, educators should focus on incorporating detailed feedback mechanisms, interactive digital platforms, and collaborative activities that simulate real-world scientific inquiry. Additionally, curriculum developers should design comprehensive IBL activities that address the identified areas of improvement, ensuring students receive a well-rounded educational experience. These insights provide valuable recommendations for educators and policymakers to optimize IBL, thereby improving educational outcomes in open distance learning environments.

REFERENCES

Abaniel, A. (2021). Enhanced Conceptual Understanding, 21st Century Skills And Learning Attitudes Through An Open Inquiry Learning Model In Physics. *Journal of Technology and Science Education*, *11*(1), 30–43.

Ahmadi, G., Mohammadi, A., Asadzandi, S., Shah, M., & Mojtahedzadeh, R. (2023). What Are the Indicators of Student Engagement in Learning Management Systems? A Systematized Review of the Literature. In I*nternational Review of Research in Open and Distributed Learning, 24*(1), 117–136.

Al-Haddad, S., Chick, N., & Safi, F. (2024). Teaching Statistics: A Technology-Enhanced Supportive Instruction (TSI) Model During the Covid-19 Pandemic and Beyond. *Journal of Statistics and Data Science Education*, *32*(2), 129–142.

Amin, A. M., Corebima, A. D., Zubaidah, S., & Mahanal, S. (2020). The Correlation Between Metacognitive Skills and Critical Thinking Skills at The Implementation of Four Different Learning Strategies in Animal Physiology Lectures. *European Journal of Educational Research*, *9*(1), 143–163.

Aston, K. J. (2023). 'Why is This Hard, to Have Critical Thinking?' Exploring the Factors Affecting Critical Thinking with International Higher Education Students. *Active Learning in Higher Education*.

Bekteshi, E., Gollopeni, B., & Avdiu, E. (2023). The Challenges of Conducting Online Inquiry-Based Learning Among Tertiary Education. *Journal of Technology and Science Education*, *13*(1), 92–103.

Chu, C., Dewey, J. L., & Zheng, W. (2023). An Inorganic Chemistry Laboratory Technique Course using Scaffolded, Inquiry-Based Laboratories and Project-Based Learning. *Journal of Chemical Education*, *100*(9), 3500–3508.

Chusni, M. M., Saputro, S., Rahardjo, S. B., & Suranto. (2020). Student's Critical Thinking Skills through Discovery Learning Model using e-Learning on Environmental Change Subject Matter. *European Journal of Educational Research*, *10*(3), 1123–1135.

Cortázar, C., Nussbaum, M., Harcha, J., Alvares, D., López, F., Goñi, J., & Cabezas, V. (2021). Promoting Critical Thinking in An Online, Project-Based Course. *Computers in Human Behavior*, 119.

Cossu, R., Awidi, I., & Nagy, J. (2024). Critical Thinking Activities in Fluid Mechanics – A Case Study for Enhanced Student Learning and Performance. *Education for Chemical Engineers*, *46,* 35–42.

Costes-Onishi, P., Baildon, M., & Aghazadeh, S. (2020). Moving Inquiry-Based Learning forward: A Meta-Synthesis on Inquiry-Based Classroom Practices for pedagogical Innovation and School Improvement in The Humanities and Arts. *Asia Pacific Journal of Education*, *40*(4), 552–575.

Coyte, E. (2023). Staff Goals, Challenges, and Use of Student Inquiry in Undergraduate Bioscience Teaching Laboratories. *FEBS Open Bio*, *13*(10), 1810–1830.

de Jong, T., Lazonder, A. W., Chinn, C. A., Fischer, F., Gobert, J., Hmelo-Silver, C. E., Koedinger, K. R., Krajcik, J. S., Kyza, E. A., Linn, M. C., Pedaste, M., Scheiter, K., & Zacharia, Z. C. (2023). Let's Talk Evidence – The Case for Combining Inquiry-Based and Direct Instruction. *Educational Research Review* (Vol. 39). Elsevier Ltd.

Doucette, D., Clark, R., & Singh, C. (2021). Students' Attitudes toward Experimental Physics in A Conceptual Inquiry-Based Introductory Physics Lab. *Canadian Journal of Physics, 100*(6): 292-302.

Duran, M., & Dökme, I. (2016). The Effect of The Inquiry-Based Learning Approach on Student's Critical-Thinking Skills. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(12), 2887–2908.

Fatmawati, B., & Rustaman, N. Y. (2020). The Study of Inquiry Ability in The Photosynthesis Concept. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 583–589.

Field, A. (2024). *Discovering statistics using IBM SPSS statistics*. Sage publications limited.

Ganajová, M., Sotáková, I., Lukáč, S., Ješková, Z., Jurková, V., & Orosová, R. (2021). Formative Assessment as A Tool to Enhance The Development of Inquiry Skills in Science Education. *Journal of Baltic Science Education*, *20*(2), 204–222.

Garrison, D. R. (2022). Shared Metacognition in a Community of Inquiry. *Online Learning Journal, 26*(1), 6–18.

Gómez, R. L., & Suárez, A. M. (2020). Do Inquiry-Based Teaching and School Climate Influence Science Achievement and Critical Thinking? Evidence from PISA 2015. *International Journal of STEM Education*, *7*(1).

Hsu, J. L., Atamian, H. S., & Avendano-Woodruff, K. (2024). Promoting Student Interest in Plant Biology through An Inquiry-Based Module Exploring Plant Circadian Rhythm, Gene Expression, and Defense against Insects. *Journal of Microbiology & Biology Education*, *25*(1).

Irwanto, I. (2023). Improving Preservice Chemistry Teachers' Critical Thinking and Science Process Skills using Research-Oriented Collaborative Inquiry Learning. *Journal of Technology and Science Education*, *13*(1), 23–35.

Jerrim, J., Oliver, M., & Sims, S. (2019). The Relationship between Inquiry-Based Teaching and Students' Achievement. New Evidence from A Longitudinal PISA Study in England. *Learning and Instruction*, *61*, 35–44.

Johnson, R. B., & Christensen, L. (2014). *Educational Research Quantitative Qualitative and Mixed Approaches* (5th ed.). SAGE Publications Inc.

Killpack, T. L., Fulmer, S. M., Roden, J. A., Dolce, J. L., & Skow, C. D. (2020). Increased Scaffolding and Inquiry in an Introductory Biology Lab Enhance Experimental Design Skills and Sense of Scientific Ability. *Journal of Microbiology & Biology Education*, *21*(2).

Kreher, S. A., Pavlova, I. V., & Nelms, A. (2021). An Active Learning Intervention Based on Evaluating Alternative Hypotheses Increases Scientific Literacy of Controlled Experiments in Introductory Biology. *Journal of Microbiology & Biology Education*, *22*(3).

Kumar, R. (2011). *Research Methodology: A Step-By-Step Guide for Beginners* (3rd ed.). SAGE Publications Inc.

Lameras, P., Arnab, S., de Freitas, S., Petridis, P., & Dunwell, I. (2021). Science Teachers' Experiences of Inquiry-Based Learning through A Serious Game: A Phenomenographic Perspective. *Smart Learning Environments*, *8*(1).

Li, X., Zhang, Y., Yu, F., Zhang, X., Zhao, X., & Pi, Z. (2024). Do Science Teachers' Believes Related to Inquiry-Based Teaching Affect Students' Science Process Skills? Evidence from A Multilevel Model Analysis. *Disciplinary and Interdisciplinary Science Education Research*, *6(*1).

Liu, C., Bano, M., Zowghi, D., & Kearney, M. (2021). Analysing User Reviews of Inquiry-Based Learning Apps in Science Education. *Computers and Education*, 164.

Loy, H. C., Ragupathi, K., & Yeo, Z. H. (2022). Promoting Critical Thinking and Learning in a Large-Enrolment Humanities Course A Case Study. *Teaching and Learning Inquiry*, 10.

Martín-Gámez, C., Acebal, M. del C., & Prieto, T. (2020). Developing The Concept of 'Ecosystem' through Inquiry-Based Learning: A Study of Pre-Service Primary Teachers. *Journal of Biological Education*, *54*(2), 147–161.

McFadden, J. R., & Fuselier, L. (2020). Graduate Teaching Assistants: Sharing Epistemic Agency with Non-Science Majors in The Biology Laboratory. *Disciplinary and Interdisciplinary Science Education Research*, *2*(1).

McKee, F., Wolf, J. D., Simon, S., & Floyd, J. H. (2023). Teaching Transferable Skills in Teamwork, Accountability, Goal Setting, Writing, and Problem-Solving in A Non-Major Microbiology Lab: The Unknown Bacteria Experiment Redefined. *Journal of Microbiology & Biology Education*, *24*(3).

Meyers, L. S., Gamst, G. C., & Guarino, A. J. (2013). *Performing Data Analysis using IBM SPSS*. John Wiley & Sons.

Mitarlis, Ibnu, S., Rahayu, S., & Sutrisno. (2020). The Effectiveness of New Inquiry-Based Learning (NIBL) for Improving Multiple Higher-Order Thinking Skills (M-HOTS) of Prospective Chemistry Teachers. *European Journal of Educational Research*, *9*(3), 1309–1325.

Muhamad Dah, N., Mat Noor, M. S. A., Kamarudin, M. Z., & Syed Abdul Azziz, S. S. (2024). The Impacts of Open Inquiry on Students' Learning in Science: A Systematic Literature Review. *Educational Research Review* (Vol. 43). Elsevier Ltd.

Nzomo, C., Rugano, P., Njoroge Mungai, J., & Gitonga Muriithi, C. (2023). Inquiry-Based Learning and Students' Self-Efficacy in Chemistry among Secondary Schools in Kenya. *Heliyon*, *9*(1).

Öztürk, B., Kaya, M., & Demir, M. (2022). Does Inquiry-Based Learning Model Improve Learning Outcomes? A Second-Order Meta-Analysis. *Journal of Pedagogical Research*, *6(*4), 201–216.

Pereles, A., Ortega-Ruipérez, B., & Lázaro, M. (2024). The Power of Metacognitive Strategies to Enhance Critical Thinking in Online Learning. *Journal of Technology and Science Education*, *14*(3), 831–843.

Pursitasari, I. D., Suhardi, E., Putra, A. P., & Rachman, I. (2020). Enhancement of Student's Critical Thinking Skill through Science Context-Based Inquiry Learning. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 97–105.

Rahayu, U., Anam, R. S., Sekarwinahyu, M., Sapriati, A., Sudarso, Y., & Sausan, I. (2024). Exploring of Inquiry Skills of Teacher Students: Biology, Physics, and Elementary School Teacher Education. *European Journal of Education and Pedagogy*, *5*(1), 48–53.

Rahayu, U., & Sapriati, A. (2018). Open Educational Resources Based Online Tutorial Model for Developing Critical Thinking of Higher Distance Education Students. *Turkish Online Journal of Distance Education*, *19*(4), 163-175.

Sadeghi, F., Mohammad, S., Adel, R., Zareian, G., & Davoudi, M. (2020). Iranian EFL Teachers' and Learners' Perceptions of the Principles of Critical Thinking: A Constructivist Grounded Theory Study. *Iranian Journal of Language Teaching Research*, *8*(2), 63–81.

Santos-Díaz, A., Montesinos, L., Barrera-Esparza, M., del Mar Perez-Desentis, M., & Salinas-Navarro, D. E. (2024). Implementing a Challenge-Based Learning Experience in A Bioinstrumentation Blended Course. *BMC Medical Education*, *24*(1).

Song, Y., Roohr, K. C., & Kirova, D. (2024). Exploring Approaches for Developing and Evaluating Workplace Critical Thinking Skills. *Thinking Skills and Creativity*, 51.

Sotiriou, S. A., Lazoudis, A., & Bogner, F. X. (2020). Inquiry-Based Learning and E-learning: How to Serve High and Low Achievers. *Smart Learning Environments*, *7*(1).

Spence, P. L., Phillips, R. S., McAllister, A. R., White, S. L., & Hollowell, G. P. (2020). Student-Scientist Curriculum: Integrating Inquiry-Based Research Experiences and Professional Development Activities into an Introductory Biology Laboratory Course. *Journal of Microbiology & Biology Education*, *21*(3).

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2013). *Using Multivariate Statistics*. Pearson

Taghinezhad, A., & Riasati, M. J. (2020). The Interplay of Critical Thinking Explicit Instruction, Academic Writing Performance, Critical Thinking Ability, and Critical Thinking Dispositions: An Experimental Study. *International Journal of Educational Research and Innovation*, *2020*(13), 143–165.

Tirado-Olivares, S., Cózar-Gutiérrez, R., García-Olivares, R., & Antonio González-Calero, J. (2021). Active Learning in History Teaching in Higher Education: The Effect of Inquiry-Based Learning and A Student Response System-Based Formative Assessment in Teacher Training. *Australasian Journal of Educational Technology, 37*(5), 61-76

Tomesko, J., Cohen, D., & Bridenbaugh, J. (2022). Using a Virtual Flipped Classroom Model to Promote Critical Thinking in Online Graduate Ccourses in the United States: A Case Presentation. *Journal of Educational Evaluation for Health Professions*, 19.

Wale, B. D., & Bishaw, K. S. (2020). Effects of using Inquiry-Based Learning on EFL Students' Critical Thinking Skills. *Asian-Pacific Journal of Second and Foreign Language Education*, *5*(1).

Wu, X. Ben, Sandoval, C., Knight, S., Jaime, X., Macik, M., & Schielack, J. F. (2021). Web-Based Authentic Inquiry Experiences in Large Introductory Classes Consistently Associated with Significant Learning Gains for All Students. *International Journal of STEM Education*, *8*(1).