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Integrating Artificial Intelligence into Ethno-STEM Project-Based Learning to Support Students' Science Inquiry Skills in Island Schools

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Abstract
The integration of artificial intelligence (AI) into STEM education provides opportunities to support inquiry-based and student-centered learning. However, implementing AI-supported learning in remote island schools remains challenging because of limited infrastructure, restricted digital access, and contextual educational barriers. This study examines how AI integrated into Ethno-STEM Project-Based Learning (Ethno-STEM PjBL) supports students' science inquiry skills in remote island schools. A descriptive mixed-method approach was employed involving 63 junior high school students on Lae-Lae Island, Indonesia. Learning activities were conducted through four contextual Ethno-STEM projects related to local food carbon footprints, renewable energy, waste management, and traditional water filtration. AI tools were used to support information exploration, idea generation, project organization, and scientific communication. Quantitative data were collected using a science inquiry skills test covering six dimensions: observing, classifying, hypothesizing, experimenting, using tools and materials, and communicating. Qualitative data were obtained through classroom observations, project documentation, and reflective discussions. Results showed relatively high inquiry skill performance across all dimensions, with observing obtaining the highest score (87%), followed by communicating (79%) and using tools and materials (78%). Qualitative findings indicated that AI-supported inquiry activities encouraged contextual investigation, collaborative exploration, and stronger connections between scientific concepts and local cultural practices. Despite challenges related to internet connectivity and digital literacy, the study suggests that AI-integrated Ethno-STEM PjBL has strong potential to enhance science inquiry skills in geographically isolated educational settings and contributes to discussions on culturally responsive and technology-supported STEM education.

Keywords: Artificial Intelligence, Contextual Learning, Ethno-STEM, Project-Based Learning, Remote Island Schools, Science Inquiry Skills

Introduction

The rapid advancement of digital technology and artificial intelligence (AI) has significantly influenced contemporary educational practices, particularly in science and STEM education (Almasri, 2024; Chng et al., 2023). AI-supported technologies are increasingly being integrated into learning environments to assist students in accessing information, generating ideas, organizing learning tasks, and developing problem-solving strategies (Jufrida et al., 2025). In educational contexts, artificial intelligence is no longer viewed solely as a technological innovation but also as a learning support system capable of facilitating more interactive, student-centered, and inquiry-oriented learning experiences (Karampelas, 2025). The growing use of AI-assisted tools in classrooms has encouraged educators to reconsider how technology can support students' active participation and scientific inquiry processes during learning activities (Küçükuncular, 2025).

In STEM education, science inquiry skills are considered essential competencies that enable students to investigate problems, construct explanations, analyze evidence, and communicate scientific ideas effectively (Ješková et al., 2022). Inquiry skills involve various scientific processes, including observing, classifying, formulating hypotheses, conducting investigations, using tools and materials, and communicating findings. These skills are closely associated with scientific literacy because students are expected not only to understand scientific concepts but also to engage actively in the processes through which scientific knowledge is developed. Previous studies have emphasized that inquiry-oriented learning environments contribute positively to students' critical thinking, problem-solving abilities, and conceptual understanding because students participate directly in authentic scientific investigations (Morris, 2025; Saunders-Stewart et al., 2012).

Despite the increasing emphasis on inquiry-based STEM education, many schools located in remote and geographically isolated areas continue to experience substantial limitations in implementing inquiry-oriented learning practices. Schools in small island communities often face restricted access to digital learning resources, unstable internet connectivity, limited laboratory facilities, and inadequate instructional support (Maisyaroh et al., 2025). Under these conditions, science learning frequently remains teacher-centered and focused on memorization rather than exploration and investigation. As a result, students may have fewer opportunities to develop inquiry skills through meaningful scientific activities connected to real-life contexts.

These challenges indicate the importance of learning approaches that are contextual, culturally relevant, and adaptable to local educational conditions (Ibnu Fitrianto & Muhammad Farisi, 2025). One instructional approach that has attracted considerable attention in STEM education is Project-Based Learning (PjBL) (Beier et al., 2019; Diana et al., 2021). Through project-based learning, students investigate authentic problems, collaborate with peers, and develop solutions through hands-on and inquiry-oriented activities. In remote educational settings, project-based learning may provide opportunities for students to connect scientific concepts with environmental and social issues that are closely related to their daily lives (Sigit et al., 2022).

In recent years, the integration of ethno pedagogical perspectives into STEM education has further expanded the potential of contextual learning approaches. Ethno-STEM education combines scientific knowledge with local wisdom, cultural practices, and community experiences to create learning environments that are more meaningful and relevant for students. Through Ethno-STEM learning, students are encouraged to reinterpret scientific concepts through local cultural contexts and indigenous knowledge systems (Lee et al., 2023; Sumarni & Kadarwati, 2020). Previous studies have shown that Ethno-STEM Project-Based Learning can support students' conceptual understanding, critical thinking, creativity, and ecological awareness because learning activities are directly connected to contextual problems encountered within students' communities.

The integration of artificial intelligence into Ethno-STEM Project-Based Learning provides additional opportunities for supporting students' inquiry processes during contextual investigations (Jufrida et al., 2025). AI-supported tools may assist students in exploring information, generating project ideas, organizing investigations, interpreting findings, and developing digital learning products (Kim et al., 2025). Rather than replacing the role of teachers, artificial intelligence may function as cognitive scaffolding that supports students during scientific inquiry activities. In culturally responsive STEM learning environments, AI-assisted exploration may also help students connect local wisdom with broader scientific knowledge and digital resources (Okada et al., 2025).

However, most previous studies concerning artificial intelligence in education have focused primarily on technologically advanced or urban educational settings. Research examining how AI integration supports science inquiry skills within culturally responsive and context-based STEM learning environments remains limited, particularly in remote island schools. In addition, previous studies related to Ethno-STEM Project-Based Learning have predominantly emphasized ecological awareness, learning experiences, and conceptual understanding, while relatively fewer studies have investigated how AI-supported learning environments facilitate the development of students' science inquiry skills during project activities.

Therefore, this study investigates the integration of artificial intelligence into Ethno-STEM Project-Based Learning and explores how this learning approach supports students' science inquiry skills in remote island schools. The study focuses on students' inquiry processes during contextual projects involving local environmental and cultural issues, including food consumption, renewable energy, waste management, and water conservation. By examining students' inquiry activities within AI-supported contextual learning environments, this study seeks to contribute to the growing discussion regarding the role of artificial intelligence in culturally responsive STEM education and remote educational contexts.

Review of Related Literature

The integration of project-based learning (PjBL) and artificial intelligence (AI) into STEM education has been widely studied for its impact on student engagement, inquiry skills, and academic achievement. Al-Bahadli et al. (2023) demonstrated that online PjBL enhances communication, motivation, and performance, while Beier et al. (2019) and Diana et al. (2021) confirmed its effectiveness in shaping STEM attitudes and career aspirations. Dias-Oliveira et al. (2024) extended these findings to business education, showing improvements in critical thinking and teamwork.

AI-supported learning environments have emerged as transformative tools in science education. Almasri (2024) and Chng et al. (2023) highlighted AI's role in facilitating inquiry-based learning, while Karampelas (2025) and Kunnath & Botes (2025) emphasized its potential to nurture critical thinking and scientific inquiry. Studies such as Jin et al. (2023) and Gligorea et al. (2023) explored AI's contribution to self-regulated and adaptive learning, whereas Derakhshan & Taghizadeh (2025) examined its influence on higher-order thinking skills.

Culturally responsive approaches further enrich STEM pedagogy. Brown (2017) and Ibnu Fitrianto & Farisi (2025) stressed the importance of integrating local wisdom and equity-focused practices. Ethno-STEM models, as discussed by Sumarni & Kadarwati (2020) and Jufrida et al. (2025), demonstrated how contextual learning fosters creativity, ecological awareness, and cultural relevance.

Collectively, these studies reveal a convergence of AI-supported inquiry, project-based learning, and culturally responsive pedagogy. Together, they underscore the potential of integrating AI-driven tools with contextual PjBL to enhance inquiry skills, critical thinking, and meaningful engagement in STEM education, particularly in diverse and resource-limited settings.

Objective

The purpose of this research is to explore how artificial intelligence can be integrated into Ethno-STEM Project-Based Learning to enhance students' science inquiry skills in remote island schools. It focuses on contextual projects linked to local cultural and environmental issues—such as food consumption, renewable energy, waste management, and water conservation—while examining how AI-assisted tools support observation, investigation, interpretation, and communication. By aligning inquiry processes with culturally responsive pedagogy, the study seeks to advance both STEM education and AI-supported learning in resource-limited contexts.

Methodology

Research Design

This study employed a descriptive mixed-method approach to explore how the integration of artificial intelligence into Ethno-STEM Project-Based Learning (Ethno-STEM PjBL) supported students' science inquiry skills in a remote island school context (Kunnath & Botes, 2025). The study focused on examining students' inquiry processes during contextual project activities and identifying how AI-supported learning tools facilitated scientific investigation, exploration, and communication throughout the learning process. A mixed-method approach was selected to obtain a more comprehensive understanding of students' science inquiry skills within AI-supported contextual learning environments. Quantitative data were used to describe students' science inquiry skill performance across several inquiry dimensions, while qualitative data were utilized to examine students' inquiry experiences, collaborative investigation processes, and interactions during project activities. The integration of quantitative and qualitative findings enabled a deeper interpretation of how AI-supported Ethno-STEM learning functioned in geographically isolated educational settings.

Research Site and Participants

The research was conducted at a junior high school located on Lae-Lae Island, Makassar, Indonesia. Lae-Lae Island is part of the Spermonde Archipelago and represents a small island area with limited educational infrastructure and constrained access to digital learning resources. Most community members work in fisheries and small-scale economic sectors, while educational facilities and technological access remain relatively limited compared to urban schools.

The participants consisted of 63 junior high school students from Grades 7, 8, and 9 who participated in the Ethno-STEM Project-Based Learning activities. The participants were selected purposively based on their involvement in the learning program and project activities implemented during the study. All students participated in contextual project investigations designed to connect scientific inquiry with local environmental and cultural issues found in island communities.

Learning Intervention

The learning intervention was implemented through Ethno-STEM Project-Based Learning integrated with AI-supported inquiry activities. The learning program was designed to encourage students to investigate contextual environmental problems while integrating scientific concepts, local wisdom, and collaborative problem-solving activities.

Four contextual projects were implemented during the learning activities: (1) local food carbon footprint investigation, (2) mini solar photovoltaic system development, (3) bio-conversion-based waste bank project, and (4) traditional water filtration technology. These projects were selected because they reflected ecological and sociocultural issues closely related to students' daily experiences in island communities.

Artificial intelligence tools were integrated into several stages of project activities to support inquiry processes. Students utilized AI-assisted digital platforms to explore information related to environmental problems, generate project ideas, organize investigation procedures, interpret findings, and develop digital learning products. During project implementation, AI-supported tools also assisted students in comparing information sources, generating alternative solutions, and preparing project presentations. Teachers functioned as facilitators who guided students during inquiry activities, collaborative discussions, experimentation, and reflection sessions. The role of artificial intelligence in this study was positioned as cognitive support for inquiry-oriented learning rather than as a replacement for teacher instruction.

Instruments

Data collection was conducted using quantitative and qualitative instruments. Quantitative data were obtained using a science inquiry skills test developed based on several dimensions of scientific inquiry processes. The instrument consisted of 30 multiple-choice items distributed across six inquiry skill indicators: observing, classifying, formulating hypotheses, conducting experiments, using tools and materials, and communicating findings.

The inquiry skill instrument was contextualized according to the Ethno-STEM projects implemented during learning activities. Several test items were developed based on local environmental issues, including food consumption patterns, renewable energy utilization, waste management practices, and traditional water filtration systems in island communities. The instrument was designed to measure students' ability to apply scientific inquiry processes within contextual problem-solving situations.

Qualitative data were collected through classroom observations, students' project documentation, reflective discussions, and field notes recorded during project implementation. Observations focused on students' inquiry behaviors, collaborative interactions, problem-solving activities, and the use of AI-supported tools during learning activities. Documentation included students' project reports, digital learning products, photographs of project activities, and presentation materials.

Analysis

Quantitative data obtained from the science inquiry skills test were analyzed descriptively using mean scores, percentages, and category classifications for each inquiry skill dimension. The analysis was conducted to identify patterns of students' inquiry performance across the six indicators of science inquiry skills.

Qualitative data from classroom observations, reflective discussions, and project documentation were analyzed using thematic analysis. The analysis involved data reduction, coding, categorization, and interpretation to identify recurring themes related to AI-supported inquiry activities, contextual investigation, collaborative learning, and students' engagement in scientific exploration. The integration of quantitative and qualitative findings was conducted to provide a comprehensive understanding of how artificial intelligence supported science inquiry skills development within Ethno-STEM Project-Based Learning in remote island schools.

Findings and Discussion

Students' Science Inquiry Skills in AI-Integrated Ethno-STEM Project-Based Learning

The implementation of Artificial Intelligence-integrated Ethno-STEM Project-Based Learning (AI-integrated Ethno-STEM PjBL) demonstrated positive patterns in students' science inquiry skills during contextual project activities conducted in the remote island school setting. Throughout the learning process, students were actively involved in various inquiry-oriented activities, including observing environmental phenomena, classifying information and materials, formulating hypotheses, conducting simple investigations, utilizing scientific tools and materials, and communicating project findings collaboratively.

The quantitative analysis of students' science inquiry skills revealed that all inquiry dimensions achieved relatively high scores. Figure 1 presents the percentage scores of students' inquiry skills across six indicators, namely observing, classifying, hypothesizing, experimenting, using tools and materials, and communicating.

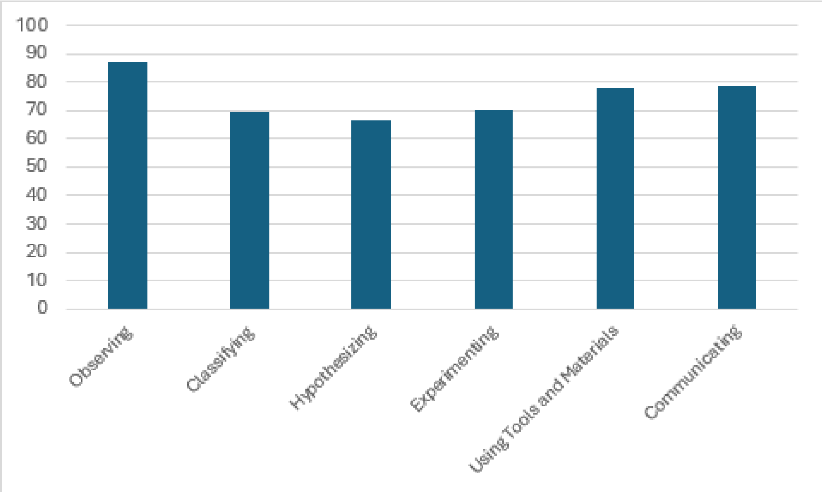

Figure 1. Students' Science Inquiry Skills in AI-Integrated Ethno-STEM Project-Based Learning

The findings indicate that the observing skill obtained the highest score (87%), followed by communicating (79%) and using tools and materials (78%). Meanwhile, classifying and experimenting each achieved a score of 70%, while hypothesizing obtained the lowest score among all indicators (67%). Although variations existed across inquiry dimensions, the results generally suggest that students demonstrated relatively strong engagement in scientific inquiry activities during project implementation.

The high score in observing skills indicates that students were able to identify and examine contextual environmental phenomena encountered in their surrounding communities. During project activities, students conducted direct observations related to local food consumption patterns, waste management practices, water conditions, and renewable energy utilization in island environments. The integration of AI-supported digital tools appeared to assist students in accessing additional information and comparing their field observations with broader scientific explanations obtained through digital exploration.

Students also demonstrated relatively strong performance in communication skills. During project implementation, students were required to present findings, discuss investigation results, and explain project solutions collaboratively. Several student groups utilized AI-assisted digital applications to prepare project presentations, organize investigation reports, and develop visual learning products such as posters and presentation slides. These activities encouraged students to communicate scientific information more systematically and confidently during collaborative learning sessions.

The using tools and materials dimension also showed relatively high achievement. Students were actively involved in utilizing scientific tools and locally available materials during project activities, particularly in the mini solar photovoltaic system project, waste management activities, and traditional water filtration experiments. Students demonstrated the ability to operate simple experimental tools, organize project materials, and conduct practical investigations related to local environmental issues. The contextual nature of the projects enabled students to connect scientific inquiry processes with everyday experiences within their island communities.

Meanwhile, the classifying and experimenting dimensions achieved moderate-to-high scores. Students were generally able to categorize information, distinguish types of waste materials, identify environmentally friendly resources, and organize investigation findings during project activities. In the experimenting dimension, students participated actively in designing simple procedures, testing project products, and evaluating investigation outcomes. However, several students still experienced difficulties in conducting systematic investigations independently and interpreting experimental results critically without teacher guidance.

Among all inquiry dimensions, hypothesizing obtained the lowest score. This finding suggests that students experienced greater challenges when formulating predictions and constructing scientific explanations before conducting investigations. During several project activities, students were more accustomed to observing and discussing directly observable phenomena rather than developing predictive reasoning based on scientific concepts. Although AI-supported tools assisted students in generating ideas and exploring possible explanations, some students still required scaffolding from teachers to formulate logical and evidence-based hypotheses.

Qualitative observations further revealed that the integration of AI into Ethno-STEM Project-Based Learning supported students' inquiry activities in several ways. AI-assisted tools helped students search for contextual information related to local ecological issues, compare alternative project ideas, and access broader scientific explanations connected to local cultural practices. Students frequently utilized AI-supported platforms during brainstorming sessions, investigation planning, and project reporting activities. These interactions encouraged collaborative exploration and strengthened students' engagement in contextual scientific inquiry.

In addition, the contextual and culturally responsive nature of Ethno-STEM projects appeared to increase students' participation during inquiry activities. Students showed greater interest when scientific investigations were directly related to familiar environmental problems and local community practices. Projects involving local food consumption, renewable energy, waste management, and traditional water filtration enabled students to connect scientific concepts with their lived experiences in island environments. This contextual connection appeared to facilitate more meaningful inquiry processes during learning activities.

Despite the positive findings, several challenges were also identified during project implementation. Limited internet connectivity occasionally disrupted AI-assisted information exploration activities, and some students experienced difficulties evaluating the reliability of AI-generated information. In addition, differences in students' prior digital literacy skills influenced their ability to utilize AI-supported tools effectively during inquiry activities. Nevertheless, collaborative learning and teacher facilitation helped students adapt to the use of AI-assisted technologies throughout the learning process.

Overall, the findings suggest that integrating artificial intelligence into Ethno-STEM Project-Based Learning may provide meaningful opportunities for supporting students' science inquiry skills in remote island schools. The combination of contextual project activities, local wisdom integration, collaborative investigation, and AI-assisted exploration created learning experiences that encouraged students to participate actively in scientific inquiry processes despite existing technological limitations.

The findings of this study indicate that the integration of artificial intelligence into Ethno-STEM Project-Based Learning (Ethno-STEM PjBL) supported students' science inquiry skills in the context of remote island schools. Overall, students demonstrated relatively strong performance across all inquiry dimensions, particularly in observing, communicating, and using tools and materials. These findings suggest that contextual and culturally responsive project activities integrated with AI-supported learning tools may create meaningful opportunities for students to engage in scientific inquiry processes despite limitations in educational infrastructure and technological access.

One of the most notable findings of this study is the high achievement in observing skills. Students were able to identify environmental phenomena, recognize contextual problems, and gather relevant information during project activities related to local food systems, waste management, renewable energy, and water conservation. The strong performance in observing skills may be closely related to the contextual nature of Ethno-STEM learning, where students investigated problems directly connected to their everyday experiences in island communities. Because students interacted with real environmental situations familiar to their social and cultural context, inquiry activities became more meaningful and easier to relate to daily life.

The integration of AI-supported tools also appeared to strengthen students' observation processes. During project implementation, students used digital platforms to search for additional explanations, compare local findings with scientific information, and explore environmental issues beyond their immediate surroundings. AI-assisted information exploration provided students with broader access to knowledge sources that may otherwise be difficult to obtain in geographically isolated schools. This finding supports the view that artificial intelligence can function as a cognitive scaffolding tool that assists students during inquiry-oriented learning activities by supporting information access, idea generation, and exploratory investigation.

Communication skills also showed relatively high achievement during project activities. Students were actively involved in presenting project findings, discussing investigation results, and developing collaborative explanations related to environmental problems encountered during learning. The project-based structure of learning encouraged students to communicate ideas more frequently through group discussions, presentations, and digital artefact creation (Al-Bahadli et al., 2023; Dias-Oliveira et al., 2024; Owens & Hite, 2022). Several groups utilized AI-assisted tools to organize project reports, prepare presentation materials, and create visual learning products, which appeared to enhance students' confidence and participation during scientific communication activities.

The improvement in communication skills may also be influenced by the collaborative nature of Ethno-STEM PjBL. Students were required to exchange ideas, negotiate solutions, and explain project outcomes to peers and teachers throughout the learning process. Such collaborative interactions are important components of inquiry-oriented STEM learning because scientific understanding is often developed through social discussion and reflective communication (Bell et al., 2010; Gillies, 2023). In addition, contextual projects grounded in local environmental issues may have encouraged students to communicate more confidently because the investigated problems were closely related to their lived experiences and community realities (Klein et al., 2021; Vare, 2021).

Another important finding is the relatively high achievement in using tools and materials. Students demonstrated the ability to utilize scientific equipment and locally available materials during contextual investigations, particularly in projects involving solar energy systems, waste management, and traditional water filtration. This finding indicates that hands-on project activities remain essential for supporting inquiry skills development, even in schools with limited laboratory infrastructure. Through contextual projects, students were not only exposed to theoretical explanations but also engaged directly in practical investigation processes that required active manipulation of tools, materials, and environmental resources (Besner & Hobbs, 2013).

Although students generally performed well across inquiry dimensions, hypothesizing showed the lowest score among all indicators. This finding suggests that constructing predictive reasoning and formulating scientific explanations remained relatively challenging for students. During several project activities, students tended to rely more on direct observation and procedural investigation than on abstract reasoning and predictive thinking. This pattern may be influenced by students' previous learning experiences, which in many remote educational contexts are still dominated by teacher-centered instruction and factual memorization rather than inquiry-oriented reasoning activities (Gligorea et al., 2023; Jin et al., 2023).

The relatively lower performance in hypothesizing also indicates that inquiry learning requires continuous scaffolding and sustained exposure to scientific reasoning practices. While AI-supported tools assisted students in generating ideas and exploring alternative explanations, students still required guidance in constructing evidence-based predictions and connecting observations with underlying scientific concepts. This finding suggests that artificial intelligence alone may not automatically strengthen higher-order inquiry processes unless accompanied by structured facilitation and reflective discussion led by teachers (Derakhshan & Taghizadeh, 2025).

The findings further demonstrate the important role of contextual and culturally responsive learning environments in supporting inquiry-oriented STEM education (Brown, 2017). Through Ethno-STEM PjBL, scientific concepts were connected with local wisdom, environmental practices, and community experiences familiar to students. Projects involving food consumption patterns, renewable energy, waste management, and water conservation enabled students to investigate scientific problems situated within their own ecological and sociocultural environment. This contextual connection likely increased students' motivation and participation during inquiry activities because learning tasks were perceived as relevant and meaningful.

An important contribution of this study lies in demonstrating that artificial intelligence integration does not necessarily diminish the role of local wisdom and contextual learning. Instead, AI-supported learning tools functioned as complementary resources that helped students expand their exploration of local environmental problems through broader scientific perspectives and digital information access. Students were able to connect traditional knowledge and local practices with scientific explanations obtained through AI-assisted inquiry activities. This finding highlights the potential of combining culturally responsive STEM learning with digital technologies in ways that preserve local identity while simultaneously supporting scientific exploration and technological literacy. The implementation of AI-integrated Ethno-STEM PjBL also revealed several practical challenges. Limited internet connectivity occasionally restricted students' ability to access digital resources consistently during project activities. Some students also experienced difficulties in evaluating the credibility and accuracy of AI-generated information. These findings indicate that effective AI integration in remote educational contexts requires adequate teacher facilitation and the development of students' critical digital literacy skills. Without appropriate guidance, students may encounter difficulties distinguishing reliable scientific information from inaccurate or oversimplified AI-generated responses (Sirnoorkar et al., 2024; Zhai et al., 2024).

Despite these limitations, the findings suggest that integrating artificial intelligence into contextual and culturally responsive project-based learning may provide promising opportunities for supporting science inquiry skills in geographically isolated schools. The combination of AI-assisted exploration, collaborative project activities, and local environmental investigation enabled students to participate more actively in inquiry-oriented learning processes. This study contributes to the growing discussion regarding artificial intelligence in education by highlighting the importance of contextual adaptation, cultural relevance, and inquiry-based pedagogy in the implementation of AI-supported STEM learning environments.

Limitations and Future Research

Several limitations should be considered when interpreting the findings of this study. First, the research was conducted in a single remote island school with a relatively limited number of participants. Although the study provides important insights into the implementation of AI-integrated Ethno-STEM Project-Based Learning in geographically isolated educational settings, the findings may not fully represent the conditions of other remote schools with different sociocultural and technological characteristics. Educational environments in island communities can vary substantially in terms of infrastructure, digital access, teacher readiness, and local cultural practices, which may influence the implementation of inquiry-oriented STEM learning.

Second, the study primarily focused on students' science inquiry skills during the implementation of contextual project activities and did not examine long-term changes in students' scientific reasoning, digital literacy, or academic achievement. The data were collected during a relatively limited intervention period, making it difficult to identify whether the observed inquiry skills could be sustained over longer learning durations. In addition, this study relied mainly on descriptive analysis and did not compare the learning outcomes with those of students experiencing conventional instructional approaches.

Another limitation concerns the integration of artificial intelligence within the learning process. In this study, AI-supported tools functioned primarily as learning support systems for information exploration, idea generation, and project development rather than as adaptive or fully personalized AI learning environments. Differences in students' digital literacy levels and familiarity with AI-assisted technologies also influenced the extent to which students utilized digital tools during inquiry activities. Furthermore, limited internet connectivity occasionally disrupted AI-supported exploration processes, which remains a significant challenge in remote educational contexts.

Future studies may expand this research by involving multiple schools from different island or rural regions to obtain broader insights into the implementation of AI-supported Ethno-STEM learning in diverse educational contexts. Longitudinal studies are also needed to examine the long-term influence of AI-integrated project-based learning on students' inquiry skills, scientific reasoning, and sustainability-oriented behaviours. In addition, future research may investigate how different forms of artificial intelligence, such as adaptive learning systems or generative AI platforms, influence students' collaborative inquiry, creativity, and problem-solving processes during STEM learning activities.

Further investigations could also explore teachers' readiness, ethical considerations, and digital equity issues related to AI integration in culturally responsive STEM education. Since AI technologies continue to develop rapidly, future studies should examine how local wisdom and indigenous knowledge can be meaningfully preserved and integrated within increasingly digitalized learning environments. Such investigations are important to ensure that technology-enhanced STEM education remains contextually relevant, culturally sensitive, and accessible for students in resource-limited educational settings.

Conclusion

This study explored the integration of artificial intelligence into Ethno-STEM Project-Based Learning and examined its role in supporting students' science inquiry skills in a remote island school context. The findings indicate that AI-integrated Ethno-STEM PjBL created meaningful opportunities for students to engage in contextual scientific inquiry activities connected to local environmental and cultural issues. Students demonstrated relatively strong performance across several inquiry dimensions, particularly in observing, communicating, and using tools and materials during project implementation. The results suggest that contextual projects grounded in local wisdom and environmental realities encouraged students to participate more actively in inquiry-oriented learning processes. Through investigations related to food consumption, renewable energy, waste management, and traditional water filtration, students were able to connect scientific concepts with their daily experiences in island communities. The integration of artificial intelligence further supported these inquiry processes by assisting students in information exploration, idea generation, project organization, and scientific communication activities.

Although hypothesizing remained the most challenging inquiry dimension, the overall findings demonstrate that AI-supported learning environments may contribute positively to the development of science inquiry skills when integrated within collaborative and culturally responsive project-based learning activities. The study also highlights that artificial intelligence does not necessarily replace local wisdom or teacher facilitation; instead, AI can function as a supportive learning resource that expands students' opportunities for contextual investigation and scientific exploration.

Overall, this study contributes to the growing discussion regarding artificial intelligence in STEM education by demonstrating the potential of AI-integrated Ethno-STEM Project-Based Learning in geographically isolated schools with limited educational resources. The combination of contextual inquiry, local wisdom integration, collaborative investigation, and AI-assisted exploration offers a promising approach for supporting meaningful and inquiry-oriented STEM learning experiences in remote educational environments.

References

Al-Bahadli, K. H., Al-Obaydi, L. H., & Pikhart, M. (2023). The Impact of the Online Project-Based Learning on Students' Communication, Engagement, Motivation, and Academic Achievement. *PSYCHOLINGUISTICS*, *33*(2), 217–237. https://doi.org/10.31470/2309-1797-2023-33-2-217-237

Almasri, F. (2024). Exploring the Impact of Artificial Intelligence in Teaching and Learning of Science: A Systematic Review of Empirical Research. *Research in Science Education*, *54*(5), 977–997. https://doi.org/10.1007/s11165-024-10176-3

Beier, M. E., Kim, M. H., Saterbak, A., Leautaud, V., Bishnoi, S., & Gilberto, J. M. (2019). The effect of authentic project-based learning on attitudes and career aspirations in STEM. *Journal of Research in Science Teaching*, *56*(1), 3–23. https://doi.org/10.1002/tea.21465

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative Inquiry Learning: Models, tools, and challenges. *International Journal of Science Education*, *32*(3), 349–377. https://doi.org/10.1080/09500690802582241

Besner, C., & Hobbs, B. (2013). Contextualized Project Management Practice: A Cluster Analysis of Practices and Best Practices. *Project Management Journal*, *44*(1), 17–34. https://doi.org/10.1002/pmj.21291

Brown, J. C. (2017). A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning. *Journal of Research in Science Teaching*, *54*(9), 1143–1173. https://doi.org/10.1002/tea.21401

Chng, E., Tan, A. L., & Tan, S. C. (2023). Examining the Use of Emerging Technologies in Schools: a Review of Artificial Intelligence and Immersive Technologies in STEM Education. *Journal for STEM Education Research*, *6*(3), 385–407. https://doi.org/10.1007/s41979-023-00092-y

Derakhshan, A., & Taghizadeh, M. S. (2025). Does Artificial Intelligence (AI) Nurture or Hinder Language Learners' Higher- Order Thinking Skills (HOTS)? A Phenomenological Study on L2 Learners' Perspectives and Lived Experiences. *International Journal of Applied Linguistics*. https://doi.org/10.1111/ijal.12824

Diana, N., Yohannes, & Sukma, Y. (2021). The effectiveness of implementing project-based learning (PjBL) model in STEM education: A literature review. *Journal of Physics: Conference Series*, *1882*(1), 012146. https://doi.org/10.1088/1742-6596/1882/1/012146

Dias-Oliveira, E., Pasion, R., Vieira da Cunha, R., & Lima Coelho, S. (2024). The development of critical thinking, team working, and communication skills in a business school–A project-based learning approach. *Thinking Skills and Creativity*, *54*, 101680. https://doi.org/10.1016/j.tsc.2024.101680

Gillies, R. M. (2023). Using Cooperative Learning to Enhance Students' Learning and Engagement during Inquiry-Based Science. *Education Sciences*, *13*(12), 1242. https://doi.org/10.3390/educsci13121242

Gligorea, I., Cioca, M., Oancea, R., Gorski, A.-T., Gorski, H., & Tudorache, P. (2023). Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. *Education*

Sciences, *13*(12), 1216. https://doi.org/10.3390/educsci13121216

Ibnu Fitrianto, & Muhammad Farisi. (2025). Integrating Local Wisdom into 21st Century Skills: A Contextual Framework for Culturally Relevant Pedagogy in Rural Classrooms. *International Journal of Post Axial: Futuristic Teaching and Learning*, 109–121. https://doi.org/10.59944/postaxial.v3i2.444

Ješková, Z., Lukáč, S., Šnajder, Ľ., Guniš, J., Klein, D., & Kireš, M. (2022). Active Learning in STEM Education with Regard to the Development of Inquiry Skills. *Education Sciences*, *12*(10), 686. https://doi.org/10.3390/educsci12100686

Jin, S.-H., Im, K., Yoo, M., Roll, I., & Seo, K. (2023). Supporting students' self-regulated learning in online learning using artificial intelligence applications. *International Journal of Educational Technology in Higher Education*, *20*(1), 37. https://doi.org/10.1186/s41239-023-00406-5

Jufrida, J., Kurniawan, W., Furqon, M., Anwar, K., Shidow Falah, H., & Riantoni, C. (2025). AI-Driven Ethnoscience Learning: Enhancing Physics Education Through Malay Cultural Insights. *Journal of Information Technology Education: Innovations in Practice*, *24*, 013. https://doi.org/10.28945/5520

Karampelas, K. (2025). Artificial intelligence in inquiry-based science teaching: A bibliometric study. *European Journal of Science and Mathematics Education*, *14*(1), 104–116. https://doi.org/10.30935/scimath/17626

Kim, J., Yu, S., Detrick, R., & Li, N. (2025). Exploring students' perspectives on Generative AI-assisted academic writing. *Education and Information Technologies*, *30*(1), 1265–1300. https://doi.org/10.1007/s10639-024-12878-7

Klein, S., Watted, S., & Zion, M. (2021). Contribution of an intergenerational sustainability leadership project to the development of students' environmental literacy. *Environmental Education Research*, *27*(12), 1723–1758. https://doi.org/10.1080/13504622.2021.1968348

Küçükuncular, A. (2025). Learning with, rather than through, AI: co-designing science education for critical AI literacy. *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1716353

Kunnath, A. J., & Botes, W. (2025). Transforming science education with artificial intelligence: Enhancing inquiry-based learning and critical thinking in South African science classrooms. *Eurasia Journal of Mathematics, Science and Technology Education*, *21*(6), em2655. https://doi.org/10.29333/ejmste/16532

Lee, D., Kim, H., & Sung, S.-H. (2023). Development research on an AI English learning support system to facilitate learner-generated-context-based learning. *Educational Technology Research and Development*, *71*(2), 629–666. https://doi.org/10.1007/s11423-022-10172-2

Maisyaroh, M., Juharyanto, J., Wiyono, B. B., Adha, M. A., Ansar, R., & Ariyanti, N. S. (2025). Enhancing hybrid learning through effective facilities management in remote settings. *Journal of Education and Learning (EduLearn)*, *19*(3), 1341–1351. https://doi.org/10.11591/edulearn.v19i3.22431

Morris, D. L. (2025). Rethinking Science Education Practices: Shifting from Investigation-Centric to Comprehensive Inquiry-Based Instruction. *Education Sciences*, *15*(1), 73.

https://doi.org/10.3390/educsci15010073

Okada, A., Sherborne, T., Panselinas, G., & Kolionis, G. (2025). Fostering Transversal Skills Through Open Schooling Supported by the CARE-KNOW-DO Pedagogical Model and the UNESCO AI Competencies Framework. *International Journal of Artificial Intelligence in Education*, *35*(4), 1953–1998. https://doi.org/10.1007/s40593-025-00458-w

Owens, A. D., & Hite, R. L. (2022). Enhancing student communication competencies in STEM using virtual global collaboration project based learning. *Research in Science & Technological Education*, *40*(1), 76–102. https://doi.org/10.1080/02635143.2020.1778663

Saunders-Stewart, K. S., Gyles, P. D. T., & Shore, B. M. (2012). Student Outcomes in Inquiry Instruction. *Journal of Advanced Academics*, *23*(1), 5–31. https://doi.org/10.1177/1932202X11429860

Sigit, D. V., Ristanto, R. H., & Mufida, S. N. (2022). Integration of Project-Based E-Learning with STEAM: An Innovative Solution to Learn Ecological Concept. *International Journal of Instruction*, *15*(3), 23–40. https://doi.org/10.29333/iji.2022.1532a

Sirnoorkar, A., Zollman, D., Laverty, J. T., Magana, A. J., Rebello, N. S., & Bryan, L. A. (2024). Student and AI responses to physics problems examined through the lenses of sensemaking and mechanistic reasoning. *Computers and Education: Artificial Intelligence*, *7*, 100318. https://doi.org/10.1016/j.caeai.2024.100318

Sumarni, W., & Kadarwati, S. (2020). Ethno-Stem Project-Based Learning: Its Impact to Critical and Creative Thinking Skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 11–21. https://doi.org/10.15294/jpii.v9i1.21754

Vare, P. (2021). Exploring the Impacts of Student-Led Sustainability Projects with Secondary School Students and Teachers. *Sustainability*, *13*(5), 2790. https://doi.org/10.3390/su13052790

Zhai, C., Wibowo, S., & Li, L. D. (2024). The effects of over-reliance on AI dialogue systems on students' cognitive abilities: a systematic review. *Smart Learning Environments*, *11*(1), 28. https://doi.org/10.1186/s40561-024-00316-7