



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

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ABSTRACT

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Artificial intelligence (AI) gives STEM education new ways to support inquiry-based, student-centered learning. Using AI-supported learning in remote island schools is still difficult, however, because of limited infrastructure, restricted digital access, and contextual barriers to education. This study examines how AI, when integrated into Ethno-STEM Project-Based Learning (Ethno-STEM PjBL), supports students' science inquiry skills in remote island schools. A descriptive mixed-method design was used with 63 junior high school students on Lae-Lae Island, Indonesia. Students worked on four contextual Ethno-STEM projects dealing with local food carbon footprints, renewable energy, waste management, and traditional water filtration. AI tools helped them explore information, generate ideas, organize their projects, and communicate scientific results. Quantitative data came from a science inquiry skills test covering six dimensions: observing, classifying, hypothesizing, experimenting, using tools and materials, and communicating. Qualitative data came from classroom observations, project documentation, and reflective discussions. Inquiry skill performance was relatively high in every dimension. Observing scored highest (87%), followed by communicating (79%) and using tools and materials (78%). The qualitative findings show that AI-supported inquiry encouraged students to investigate their own context, explore together, and link scientific concepts more closely with local cultural practices. Internet connectivity and digital literacy remained problems. Even so, the study suggests that AI-integrated Ethno-STEM PjBL has strong potential to improve science inquiry skills in geographically isolated schools, and it adds to the discussion on culturally responsive, technology-supported STEM education.

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

Background

Digital technology and artificial intelligence (AI) have changed much of today's educational practice, and science and STEM education are no exception (Almasri, 2024; Chng *et al.*, 2023). Schools are bringing AI-supported technologies into the classroom to help students find information, generate ideas, organize learning tasks, and work out problem-solving strategies (Evains *et al.*, 2024; Jufrida *et al.*, 2025). AI is therefore no longer seen only as a technological innovation. It is also treated as a learning support system that can make learning more interactive, student-centered, and inquiry-oriented (Karampelas, 2025). As AI-assisted tools spread through classrooms, educators have begun to rethink how technology can support students' active participation and their scientific inquiry during lessons (Küçükuncular, 2025).

Science inquiry skills are regarded as essential competencies in STEM education. They allow students to investigate problems, build explanations, analyze evidence, and communicate scientific ideas effectively (Ješková *et al.*, 2022). Inquiry draws on several scientific processes: observing, classifying, formulating hypotheses, conducting investigations, using tools and materials, and communicating findings. These skills are closely tied to scientific literacy, because students are expected not only to understand scientific concepts but also to take an active part in the processes through which scientific knowledge is built. Earlier studies have stressed that inquiry-oriented learning environments improve students' critical thinking, problem-solving abilities, and conceptual understanding, since students take part directly in authentic scientific investigations (Morris, 2025; Saunders-Stewart *et al.*, 2012).

Inquiry-based STEM education is receiving more and more emphasis, yet many schools in remote and geographically isolated areas still struggle to put inquiry-oriented practices in place. Schools in small island communities often have restricted access to digital learning resources, unstable internet connections, limited laboratory facilities, and inadequate instructional support (Maisyaroh *et al.*, 2025). In these conditions, science lessons frequently stay teacher-centered and focus on memorization instead of exploration and investigation. Students may therefore have fewer chances to develop inquiry skills through meaningful scientific activities linked to real-life contexts.

Such challenges point to the need for learning approaches that are contextual, culturally relevant, and adaptable to local educational conditions (Ibnu Fitrianto & Muhammad Farisi, 2025). Project-Based Learning (PjBL) is one approach that has drawn considerable attention in STEM education (Beier *et al.*, 2019; Diana *et al.*, 2021). In project-based learning, students investigate authentic problems, work with their peers, and develop solutions through hands-on, inquiry-oriented activities. In remote settings, it can give students the chance to connect scientific concepts with the environmental and social issues of their daily lives (Sigit *et al.*, 2022).

In recent years, ethnopedagogical perspectives have widened what contextual learning approaches can offer in STEM education. Ethno-STEM education brings scientific knowledge together with local wisdom, cultural practices, and community experience, so that learning environments become more meaningful and relevant to students. In Ethno-STEM learning, students are encouraged to reinterpret scientific concepts through their local cultural contexts and indigenous knowledge systems (Lee *et al.*, 2023; Sumarni & Kadarwati, 2020). Earlier studies show that Ethno-STEM Project-Based Learning can support students' conceptual understanding, critical thinking, creativity, and ecological awareness, because the learning activities deal directly with problems found in the students' own communities.

Bringing artificial intelligence into Ethno-STEM Project-Based Learning opens further ways to support students' inquiry during contextual investigations (Jufrida *et al.*, 2025). AI-supported tools can help students explore information, generate project ideas, organize investigations, interpret findings, and

produce digital learning products (Kim *et al.*, 2025). AI is not meant to replace the teacher. Instead, it can act as cognitive scaffolding that supports students during scientific inquiry. In culturally responsive STEM learning environments, AI-assisted exploration may also help students link local wisdom with broader scientific knowledge and digital resources (Okada *et al.*, 2025).

Most earlier research on AI in education, however, has been carried out in technologically advanced or urban settings. Little is known about how AI integration supports science inquiry skills in culturally responsive, context-based STEM learning environments, particularly in remote island schools. Studies of Ethno-STEM Project-Based Learning have mostly looked at ecological awareness, learning experiences, and conceptual understanding. Fewer have examined how AI-supported learning environments help students develop science inquiry skills during project activities.

Objectives

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

Literature Review

Artificial intelligence (AI) is increasingly being built into science and STEM education, and there is evidence that AI-supported technologies can help with learning, access to information, and inquiry-oriented activities (Almasri, 2024; Chng *et al.*, 2023). AI can support students as they explore information, generate ideas, and take part in inquiry, but effective use depends on appropriate pedagogical guidance (Karampelas, 2025; Kunnath & Botes, 2025). Project-Based Learning (PjBL) complements this by engaging students in authentic problems, collaborative investigation, and practical problem-solving. Research shows that STEM-oriented PjBL can improve students' learning and engagement (Beier *et al.*, 2019; Diana *et al.*, 2021). In culturally responsive education, Ethno-STEM links scientific concepts with local knowledge and community practices. Sumarni and Kadarwati (2020) found that Ethno-STEM PjBL can strengthen students' critical and creative thinking, and Brown (2017) pointed to the value of combining culturally responsive and inquiry-based science education.

More recent work has started to examine AI in ethnoscience contexts and shows that it can help connect cultural knowledge with science learning (Jufrida *et al.*, 2025). Evidence is still limited, though, on how AI-integrated Ethno-STEM PjBL develops specific science inquiry skills, especially in remote, resource-constrained island schools. This gap is the rationale for the present study.

Methods

Research Design

A descriptive mixed-method approach was used to explore how integrating artificial intelligence into Ethno-STEM Project-Based Learning (Ethno-STEM PjBL) supported students' science inquiry skills in a remote island school (Kunnath & Botes, 2025). The study examined students' inquiry processes during contextual project activities and looked at how AI-supported learning tools helped with scientific investigation, exploration, and communication throughout the learning process.

The mixed-method approach was chosen to gain a fuller understanding of students' science inquiry skills in AI-supported contextual learning environments. Quantitative data described students' performance on several inquiry dimensions, while qualitative data were used to examine their inquiry experiences, collaborative investigation, and interactions during project activities. Combining the two kinds of findings allowed a deeper interpretation of how AI-supported Ethno-STEM learning worked in geographically isolated schools.

Research Site and Participants

The study took place at a junior high school on Lae-Lae Island, Makassar, Indonesia. Lae-Lae Island belongs to the Spermonde Archipelago. It is a small island with limited educational infrastructure and restricted access to digital learning resources. Most residents work in fisheries and small-scale economic activities, and educational facilities and access to technology remain relatively limited compared with urban schools.

Participants were 63 junior high school students from Grades 7, 8, and 9 who took part in the Ethno-STEM Project-Based Learning activities. They were selected purposively, based on their involvement in the learning program and the project activities carried out during the study. All of them took part in contextual project investigations designed to connect scientific inquiry with local environmental and cultural issues in island communities.

Learning Intervention

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

The learning activities consisted of four contextual projects: (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 chosen because they reflect ecological and sociocultural issues that are part of students' daily lives in island communities.

AI tools were built into several stages of the projects to support inquiry. Students used AI-assisted digital platforms to explore information on environmental problems, generate project ideas, organize investigation procedures, interpret findings, and develop digital learning products. While carrying out the projects, they also used AI-supported tools to compare information sources, generate alternative solutions, and prepare project presentations.

Teachers acted as facilitators, guiding students during inquiry activities, collaborative discussions, experimentation, and reflection sessions. In this study, AI was positioned as cognitive support for inquiry-oriented learning, not as a replacement for teacher instruction.

Instruments

Both quantitative and qualitative instruments were used. Quantitative data came from a 30-item multiple-choice science inquiry skills test covering six indicators: observing, classifying, hypothesizing, experimenting, using tools and materials, and communicating. The test was contextualized to the Ethno-STEM projects. Its items drew on local environmental issues, including food consumption, renewable energy, waste management, and traditional water filtration, so that students' inquiry skills were assessed in contextual problem-solving situations.

Qualitative data was gathered through classroom observations, project documentation, reflective discussions, and field notes during the projects. These data concentrated on students' inquiry behaviors,

collaborative interactions, problem-solving processes, and use of AI-supported tools. Project reports, digital learning products, photographs, and presentation materials were also analyzed to support the findings.

Data Analysis

Quantitative data from the science inquiry skills test were analyzed descriptively with mean scores, percentages, and category classifications, showing how students performed on each of the six inquiry skill indicators.

Qualitative data from classroom observations, reflective discussions, and project documentation were analyzed thematically. Coding, categorization, and interpretation were used to identify themes related to AI-supported inquiry, contextual investigation, collaborative learning, and student engagement. The quantitative and qualitative findings were then integrated to give a comprehensive picture of how AI supported science inquiry skills in Ethno-STEM Project-Based Learning in remote island schools.

Results and Discussion

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

Implementing Artificial Intelligence-integrated Ethno-STEM Project-Based Learning (AI-integrated Ethno-STEM PjBL) produced positive patterns in students' science inquiry skills during the contextual project activities at the remote island school. Throughout the learning process, students took an active part in a range of inquiry-oriented activities. They observed environmental phenomena, classified information and materials, formulated hypotheses, carried out simple investigations, used scientific tools and materials, and communicated project findings together.

The quantitative analysis showed relatively high scores on all inquiry dimensions. Figure 1 gives the percentage scores for the six indicators: observing, classifying, hypothesizing, experimenting, using tools and materials, and communicating.

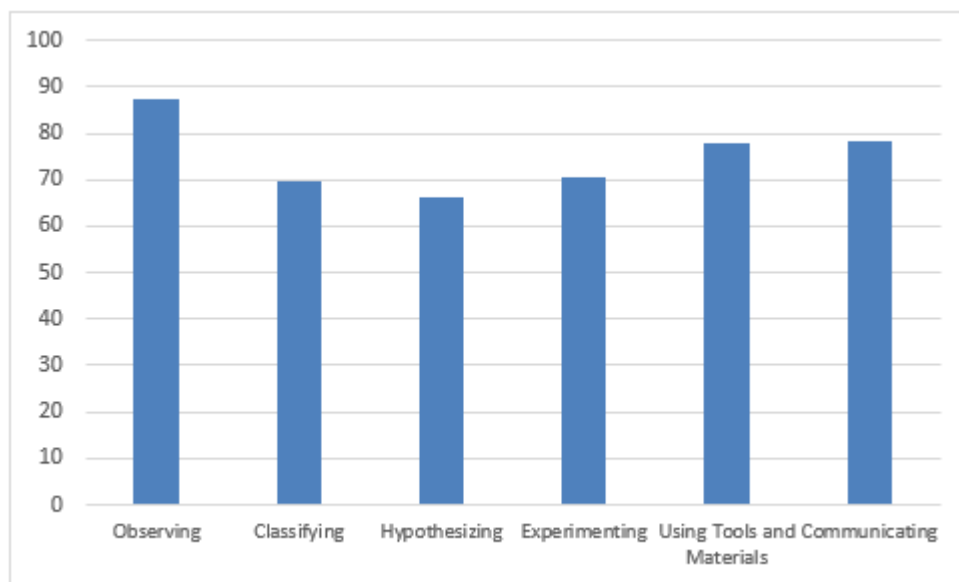


Figure 1. Students' Science Inquiry Skills in AI-Integrated Ethno-STEM Project-Based Learning

Observing obtained the highest score (87%), followed by communicating (79%) and using tools and materials (78%). Classifying and experimenting each scored 70%, and hypothesizing had the lowest score of all indicators (67%). Although the dimensions varied, the results generally suggest that students engaged relatively strongly in scientific inquiry during the projects.

The high observing score indicates that students could identify and examine environmental phenomena in their own surroundings. During the projects, they made direct observations of local food consumption patterns, waste management practices, water conditions, and the use of renewable energy on the island. The AI-supported digital tools appeared to help them access additional information and compare their field observations with the broader scientific explanations they found through digital exploration.

Students also performed relatively well in communication. During the projects, they had to present findings, discuss investigation results, and explain project solutions together. Several groups used AI-assisted digital applications to prepare presentations, organize investigation reports, and produce visual learning products such as posters and presentation slides. These activities encouraged students to communicate scientific information more systematically and with more confidence during collaborative sessions.

Achievement in using tools and materials was also relatively high. Students made effective use of scientific tools and locally available materials in the projects on mini solar photovoltaic systems, waste management, and traditional water filtration. These contextual activities let them apply scientific inquiry processes to everyday environmental issues in their island communities.

Classifying and experimenting reached moderate-to-high scores. Students were generally able to classify information, distinguish types of waste, identify environmentally friendly resources, and organize their investigation findings. They also took an active part in designing procedures, testing project products, and evaluating outcomes, although some still needed teacher guidance to carry out systematic investigations and interpret experimental results critically. Hypothesizing had the lowest score of all dimensions, which indicates that students found it harder to formulate predictions and construct scientific explanations before an investigation. AI-supported tools helped them generate ideas and explore possible explanations, but many still needed teacher scaffolding to develop logical, evidence-based hypotheses.

Qualitative observations also showed that AI supported students' inquiry by helping with contextual information searches, idea generation, investigation planning, and project reporting. Using AI-assisted platforms in these activities encouraged collaborative exploration and strengthened students' engagement in contextual scientific inquiry. The contextual and culturally responsive nature of the Ethno-STEM projects also increased students' participation in inquiry. Projects on local food consumption, renewable energy, waste management, and traditional water filtration allowed students to connect scientific concepts with their lived experiences, which made inquiry more meaningful.

Some challenges also emerged during the projects. Limited internet connectivity sometimes interrupted AI-assisted information searches, and differences in digital literacy affected how well students could use AI-supported tools. Collaborative learning and teacher facilitation nevertheless helped students adapt to these technologies.

Overall, the findings suggest that integrating artificial intelligence into Ethno-STEM Project-Based Learning offers meaningful opportunities to support students' science inquiry skills in remote island schools. Contextual projects, local wisdom, collaborative investigation, and AI-assisted exploration together encouraged active participation in scientific inquiry despite technological limitations.

This study found that integrating artificial intelligence into Ethno-STEM Project-Based Learning (Ethno-STEM PjBL) supported students' science inquiry skills in remote island schools. Students performed relatively well on all inquiry dimensions, especially observing, communicating, and using tools and materials. These results suggest that contextual, culturally responsive project activities combined with AI-supported learning tools may give students meaningful opportunities to engage in scientific inquiry, even where educational infrastructure and access to technology are limited.

One of the most notable results is the high achievement in observing. Students identified environmental phenomena, recognized contextual problems, and gathered relevant information during projects on local food systems, waste management, renewable energy, and water conservation. This strong performance may be closely linked to the contextual nature of Ethno-STEM learning, in which students investigated problems drawn from their everyday experiences in island communities. Because students worked with real environmental situations that were familiar in their social and cultural context, inquiry activities became more meaningful and easier to relate to daily life.

AI-supported tools also seemed to strengthen students' observation. During the projects, students used digital platforms to look for further explanations, compare local findings with scientific information, and explore environmental issues beyond their immediate surroundings. AI-assisted searching gave students wider access to knowledge sources that can be hard to obtain in geographically isolated schools. This supports the view that artificial intelligence can work as a cognitive scaffolding tool in inquiry-oriented learning, helping with information access, idea generation, and exploratory investigation.

Communication skills were also relatively high during the project activities. Students presented project findings, discussed investigation results, and built collaborative explanations of the environmental problems they encountered. The project-based structure gave students more occasions to communicate ideas through group discussions, presentations, and the creation of digital artifacts (Al-Bahadli *et al.*, 2023; Dias-Oliveira *et al.*, 2024; Owens & Hite, 2022). Several groups used AI-assisted tools to organize project reports, prepare presentation materials, and create visual learning products, which appeared to increase students' confidence and participation in scientific communication.

The collaborative nature of Ethno-STEM PjBL may also explain the improvement in communication. Students had to exchange ideas, negotiate solutions, and explain project outcomes to peers and teachers throughout the learning process. Such interaction is an important part of inquiry-oriented STEM learning, because scientific understanding often develops through social discussion and reflective communication (Bell *et al.*, 2010; Gillies, 2023). Contextual projects based on local environmental issues may also have helped students communicate more confidently, since the problems they investigated were close to their lived experiences and community realities (Klein *et al.*, 2021; Vare, 2021).

Another important finding concerns the use of tools and materials, where achievement was relatively high. Students showed that they could use scientific equipment and locally available materials during contextual investigations, especially in the projects on solar energy systems, waste management, and traditional water filtration. This indicates that hands-on project work remains essential for developing inquiry skills, even in schools with limited laboratory infrastructure. In the contextual projects, students did not just hear theoretical explanations; they took part directly in practical investigations that required them to handle tools, materials, and environmental resources (Besner & Hobbs, 2013; Evains *et al.*, 2024).

Although students generally performed well, hypothesizing had the lowest score of all indicators. Building predictive reasoning and formulating scientific explanations thus remained fairly difficult for them. In several projects, students relied more on direct observation and procedural investigation than on abstract

reasoning and prediction. This pattern may reflect their earlier learning experiences, which in many remote schools are still dominated by teacher-centered instruction and memorization of facts rather than inquiry-oriented reasoning (Gligorea *et al.*, 2023; Jin *et al.*, 2023).

The lower hypothesizing score also shows that inquiry learning needs continuous scaffolding and sustained practice in scientific reasoning. AI-supported tools helped students generate ideas and explore alternative explanations, but students still needed guidance to build evidence-based predictions and connect their observations with the underlying scientific concepts. Artificial intelligence on its own, then, may not strengthen higher-order inquiry processes unless teachers provide structured facilitation and lead reflective discussion (Derakhshan & Taghizadeh, 2025).

The findings also show how important contextual and culturally responsive learning environments are for inquiry-oriented STEM education (Brown, 2017). In Ethno-STEM PjBL, scientific concepts were connected with local wisdom, environmental practices, and community experiences that students knew well. Projects on food consumption patterns, renewable energy, waste management, and water conservation allowed students to investigate scientific problems set in their own ecological and sociocultural environment. This connection probably increased students' motivation and participation, because they saw the learning tasks as relevant and meaningful.

An important contribution of this study is to show that integrating artificial intelligence does not necessarily weaken the role of local wisdom and contextual learning. AI-supported tools served as complementary resources that helped students widen their exploration of local environmental problems through broader scientific perspectives and access to digital information. Students were able to connect traditional knowledge and local practices with scientific explanations obtained through AI-assisted inquiry. This points to the potential of combining culturally responsive STEM learning with digital technologies in ways that preserve local identity while also supporting scientific exploration and technological literacy.

Implementing AI-integrated Ethno-STEM PjBL also raised several practical challenges. Limited internet connectivity sometimes prevented students from accessing digital resources consistently during the projects. Some students also had difficulty judging the credibility and accuracy of AI-generated information. Effective AI integration in remote schools therefore requires adequate teacher facilitation and the development of students' critical digital literacy. Without proper guidance, students may struggle to tell reliable scientific information apart 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 offer promising ways to support science inquiry skills in geographically isolated schools. AI-assisted exploration, collaborative project work, and investigation of the local environment together enabled students to take a more active part in inquiry-oriented learning. The study adds to the growing discussion on artificial intelligence in education by highlighting the importance of contextual adaptation, cultural relevance, and inquiry-based pedagogy when AI-supported STEM learning environments are put into practice.

Limitations and Future Research

This study has some limitations. First, it was carried out in one remote island school with a limited number of participants, so the findings may not generalize to settings with different sociocultural, technological, and infrastructural conditions. Second, it looked at students' science inquiry skills over a relatively short intervention and did not examine long-term outcomes such as scientific reasoning, digital literacy, or academic achievement. In addition, AI-supported tools were used mainly for information exploration and

project development, not as adaptive learning systems, and limited internet connectivity and differences in students' digital literacy affected how they were used.

Future research should include several schools in different island or rural contexts so that the findings can be generalized more widely. Longitudinal studies are needed to examine the long-term effects of AI-integrated Ethno-STEM Project-Based Learning on inquiry skills, scientific reasoning, and sustainability-related outcomes. Future studies should also explore adaptive and generative AI, as well as teacher readiness, digital equity, and the preservation of local wisdom in AI-supported STEM education.

Conclusion

This study explored how integrating artificial intelligence into Ethno-STEM Project-Based Learning (Ethno-STEM PjBL) supported students' science inquiry skills in a remote island school. AI-integrated Ethno-STEM PjBL gave students meaningful opportunities to engage in contextual scientific inquiry on local environmental and cultural issues. Students performed relatively well, particularly in observing, communicating, and using tools and materials during the projects. The results suggest that contextual projects grounded in local wisdom encouraged students to connect scientific concepts with their everyday experiences through investigations of food consumption, renewable energy, waste management, and traditional water filtration. AI-supported tools further strengthened inquiry by helping with information exploration, idea generation, project organization, and scientific communication.

Hypothesizing remained the most challenging inquiry dimension. Even so, the findings indicate that AI can effectively support science inquiry when it is part of collaborative and culturally responsive project-based learning. Overall, the study shows the potential of AI-integrated Ethno-STEM PjBL to promote meaningful, inquiry-oriented STEM learning in geographically isolated schools with limited educational resources.

Declarations

Ethics Approval and Consent to Participate: Ethical considerations were respected throughout the study. Informed consent was obtained from all participants and from the school administration before data collection. Participation was voluntary, and participants' identities and personal information were kept anonymous and treated as confidential, for research purposes only.

AI Assistance: To improve the clarity, language quality, and readability of the manuscript, the authors made use of an automated language-editing tool during its preparation.

Conflict of interest: Not applicable.

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Authors' contributions: Sundari Hamid conceived and designed the study. All authors contributed to data interpretation, manuscript preparation, critical revision, and approved the final version of the manuscript.

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