Al-Ishlah: Jurnal Pendidikan
Vol.18, 2 (June, 2026), pp. 2711-2721
ISSN: 2087-9490 EISSN: 2597-940X, DOI: 10.35445/alishlah.v18i2.9845

Integrating Indigenous Ethnoastronomy into Science Learning: A Case Study of Galela Fishermen

Adiyana Adam[1*], Aziz Los'en[2], Erina Junaedi[3], Khalid Hasan Minabari[4]

[1] Institut Agama Islam Negeri Ternate, Indonesia; adiyanaadam@iain-ternate.ac.id
[2] Sekolah Tinggi Agama Islam Babussalam Sula, Indonesia; azillosen@gmail.com
[3] Sekolah Tinggi Agama Islam Babussalam Sula, Indonesia; erinajunaedi546@gmail.com
[4] Institut Agama Islam Negeri Ternate, Indonesia; khalidminabari@iain-ternate.ac.id

ARTICLE INFO

Keywords:

ethnoastronomy;
multicultural science education;
Galela fishermen;
MIE-Galela;
epistemic justice

Article history:

Received 2026-04-07
Revised 2026-05-03
Accepted 2026-06-30

ABSTRACT

Indigenous astronomical knowledge represents a valuable yet underutilized resource for culturally responsive science education. Although Indonesia's Merdeka Curriculum encourages the integration of local knowledge into classroom learning, empirical studies documenting indigenous ethnoastronomy in eastern Indonesia and translating it into pedagogically applicable models remain scarce. This study documents the ethnoastronomical knowledge of the Galela fishing community, examines its alignment with junior secondary science concepts, and develops an integration model grounded in epistemic justice. A qualitative ethnographic design was employed involving eight purposively selected informants representing three generations and both genders. Data were collected through participant observation, in-depth interviews, and a Focus Group Discussion, and analyzed using thematic analysis with triangulation, member checking, and peer debriefing to ensure trustworthiness. Four interconnected ethnoastronomical components were identified: stellar navigation, a lunar fishing calendar, monsoon prediction, and ethno-meteorological observation. The findings reveal substantial cross-generational knowledge erosion and uncover gender-specific ecological knowledge contributed exclusively by female informants. Based on these findings, the study proposes the MIE-Galela model, comprising Recognition, Dialogisation, Validation, and Contextualisation. The model's principal innovation lies in the Validation phase, which operationalizes epistemic justice by reframing classroom inquiry toward understanding why indigenous knowledge functions effectively rather than questioning its legitimacy. This study advances multicultural science education by demonstrating how indigenous knowledge can be integrated as a legitimate epistemic partner in science learning, providing a culturally responsive framework for strengthening scientific literacy, cultural sustainability, and epistemic inclusion.

Corresponding Author:
Adiyana Adam
Institut Agama Islam Negeri Ternate, Indonesia; adiyanaadam@iain-ternate.ac.id

1. INTRODUCTION

Indigenous knowledge has increasingly been recognized as a valuable intellectual resource for enriching science education by broadening the ways in which scientific understanding is constructed, interpreted, and applied. Contemporary science education no longer views scientific knowledge exclusively through the lens of Western Modern Science (WMS); instead, it acknowledges that diverse cultural communities have developed sophisticated systems of environmental observation through centuries of interaction with their local ecosystems (Aikenhead & Ogawa, 2007). This paradigm shift is reflected in the growing movement toward multicultural and decolonizing science education, which advocates the recognition of Indigenous knowledge as a legitimate epistemic partner capable of complementing scientific inquiry while fostering cultural sustainability and educational inclusion (Dierking et al., 2010). Such an approach enables science classrooms to become spaces where multiple knowledge traditions interact critically rather than environments in which local knowledge is merely presented as cultural heritage.

Among the diverse forms of Indigenous knowledge, ethnoastronomy occupies a particularly important position because it integrates long-term observations of celestial phenomena with ecological adaptation, navigation, agriculture, seasonal forecasting, and natural resource management. Indigenous communities throughout the world have developed highly systematic interpretations of stars, lunar cycles, planetary movements, and atmospheric phenomena to guide everyday decision-making. Previous studies have documented sophisticated ethnoastronomical systems among Aboriginal Australians, Andean agricultural communities, and Austronesian maritime societies, demonstrating that these knowledge systems are based on cumulative empirical observations refined across generations rather than arbitrary cultural beliefs (Lewis, 1978; Norris & Hamacher, 2013; Urton, 1981). Consequently, integrating ethnoastronomy into science education not only enriches scientific literacy but also enables students to understand the cultural diversity of scientific practices and appreciate the relationship between local experience and universal scientific concepts.

Indonesia provides a particularly important context for this discussion because of its extraordinary cultural and ecological diversity. As an archipelagic nation comprising thousands of islands and hundreds of ethnic groups, Indonesia possesses an extensive range of Indigenous environmental knowledge that remains largely underrepresented in formal education. The implementation of the Merdeka Curriculum has created significant opportunities for integrating local wisdom into classroom learning through contextual, inquiry-based, and culturally responsive pedagogical approaches. Furthermore, the curriculum emphasizes the *Bhinneka Tunggal Ika* dimension of the Pancasila Student Profile, encouraging learners to appreciate cultural diversity while developing critical and scientific thinking (Menteri Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2022). Despite this policy direction, practical instructional models demonstrating how Indigenous knowledge can be meaningfully incorporated into science learning remain limited, particularly in eastern Indonesia, where many Indigenous knowledge traditions have yet to be systematically documented.

One such community is the Galela fishing community in North Halmahera, North Maluku. For generations, Galela fishermen have relied on observations of stars, lunar phases, cloud formations, wind direction, and seasonal environmental changes to determine navigation routes, predict monsoon transitions, identify productive fishing periods, and ensure maritime safety. These observations constitute a coherent ethnoastronomical system developed through continuous interaction with the marine environment. Nevertheless, unlike Indigenous astronomical traditions documented among the Bugis, Javanese, and Balinese communities (Aisyah & Syam, 2024; Faricha, 2023; Sarini & Selamet, 2019), the Galela knowledge system has not previously been examined in academic literature. Consequently, an important body of Indigenous scientific knowledge remains undocumented despite its considerable educational and cultural significance.

Previous studies have proposed several approaches for integrating Indigenous knowledge into science education. Aikenhead (2001) introduced the concept of cultural border crossing, emphasizing explicit dialogue between Indigenous and Western scientific perspectives. Cobern and Loving (2001) further argued that science education should recognize multiple knowledge traditions without subordinating Indigenous perspectives to Western science. More recently, the Ethno-Inquiry model has demonstrated how local cultural practices can be incorporated into inquiry-based science learning (Oviana et al., 2025). Although these models have substantially advanced multicultural science education, three important limitations remain. First, they have rarely been developed within maritime communities, despite the unique ecological characteristics of coastal and island societies. Second, most studies overlook gender as a source of epistemic diversity, potentially excluding ecological knowledge maintained by women. Third, and most importantly, existing integration models rarely operationalize epistemic justice as a concrete pedagogical principle. While Fricker's (2007) concept of epistemic justice has become increasingly influential in educational theory, it has seldom been translated into practical classroom strategies capable of addressing testimonial and hermeneutical injustice experienced by Indigenous communities.

This study addresses these gaps by documenting the ethnoastronomical knowledge of the Galela fishing community, examining its relationship with junior secondary science concepts within Indonesia's Merdeka Curriculum, and developing an instructional framework that integrates Indigenous knowledge through the perspective of epistemic justice. Rather than positioning local knowledge merely as contextual enrichment, the proposed model recognizes Indigenous knowledge holders as legitimate producers of scientific understanding whose experiences contribute meaningfully to classroom inquiry. The study therefore introduces the MIE-Galela (Galela Ethnoastronomy Integration Model), a four-phase framework consisting of Recognition, Dialogisation, Validation, and Contextualisation. Unlike previous ethnoscience integration models, MIE-Galela explicitly operationalizes epistemic justice by shifting classroom inquiry from asking whether Indigenous knowledge is scientifically correct to investigating why it has functioned effectively through sustained empirical observation across generations. In doing so, the study contributes to multicultural science education by demonstrating how Indigenous knowledge can serve simultaneously as a source of scientific learning, cultural preservation, and epistemic inclusion within contemporary science classrooms.

2. METHODS

2.1 Research Design

This study employed a qualitative ethnographic design, selected as the most epistemologically appropriate framework for developing a deep, contextually grounded understanding of a cultural community's knowledge system as it is lived and practiced (Creswell & Creswell, 2017). Ethnography is particularly suited to this inquiry because the research questions concern the meaning, structure, and intergenerational transmission of indigenous knowledge phenomena that demand sustained engagement with the community and resist adequate capture through numerical measurement.

2.2 Ethical Considerations

This study was conducted in full compliance with internationally recognised ethical standards for qualitative research involving human participants, consistent with the principles outlined in the Declaration of Helsinki and the ethical guidelines of the American Psychological Association. Prior to data collection, all informants received a comprehensive explanation of the study's purpose, procedures, the voluntary nature of participation, their unconditional right to withdraw at any time without consequence, and the confidentiality measures applied through pseudonymisation. Verbal informed consent was obtained and audio-recorded at the commencement of each session. No financial incentives or coercion of any kind were employed. While formal Institutional Review Board (IRB) approval was not mandated as the study involved non-sensitive interviews with adult community members in a non-clinical context, all data collection and reporting procedures were designed and executed in accordance with international qualitative research ethics standards (Lincoln & Guba, 1985)(Creswell & Creswell, 2017);

2.3 Participants

Eight key informants were purposively selected from three fishing settlements in Galela District, North Halmahera Regency: Bartaku Village, Limau Village, and Soasio Village. The selection ensured four forms of representational diversity: generational (senior, middle, and younger fishermen), gender (male and female active fishermen), role (fishermen, traditional leader, and science teacher), and epistemological standpoint (indigenous knowledge holders and a formal science educator). Thematic saturation was reached by the twentieth interview session. Table 1 presents the informant profiles.

Table 1. Profile of Key Informants

No.	Pseudonym	Age	Village	Role	Years Fishing	Primary Knowledge Domain
1	Mr. AM	88	Bartaku	Senior fisherman; knowledge custodian	±70 yrs	Pariama star, Ngo-osa calendar, navigation
2	Mr. YB	72	Bartaku	Senior fisherman; group leader	±55 yrs	Skipjack star patterns, monsoon indicators
3	Mr. HR	65	Soasio	Senior fisherman; traditional leader	±45 yrs	Ethro-meteorology; cloud and wind reading
4	Mr. FT	48	Bartaku	Mid-generation fisherman	±28 yrs	Star knowledge integrated with GPS
5	Ms. SR	44	Limau	Female fisherman	±20 yrs	Lunar phases; fish ecology; phototaxis
6	Mr. MK	35	Limau	Young fisherman; SMA graduate	±15 yrs	Local knowledge vs. school science
7	Elder GS	61	Bartaku	Clan leader (soa) of Galela	N/A	Cultural context; *adat* knowledge legitimacy
8	Teacher BL	39	Tobelo*	Grade VII science teacher	N/A	Curriculum relevance; pedagogical perspective

**Recruited from outside the fishing community to minimise confirmation bias.*

2.4 Data Collection

Three complementary instruments were deployed. First, a participant observation protocol guided twelve night-time fishing excursions (21:00–04:00), capturing celestial phenomena attended to, decision-making processes, local terminology, and social contexts of knowledge use. Second, a semi-structured interview guide organised around four thematic domains knowledge content, transmission mechanisms, practical application, and perceptions of local versus modern science was used across twenty-four sessions (60–90 minutes each), all audio-recorded and transcribed verbatim. Third, one Focus Group Discussion (FGD) of approximately two hours was conducted at Bartaku Village with four senior informants (Informants 1, 2, 3, and 7) to collectively validate and elaborate patterns identified in individual interviews.

2.5 Data Analysis

Data analysis followed the three-stage framework of Miles, Huberman, and Saldaña (2014). In Stage 1 (data condensation), all transcripts, field notes, and FGD records were subjected to a three-level coding process: *open coding* generated 31 initial codes inductively from the first six transcripts; *axial coding* reorganised these into 12 focused codes by identifying relationships and categories across the data; and *selective coding* consolidated the focused codes into four overarching themes, each corresponding to one principal ethroastronomical component. In Stage 2 (data display), thematic matrices and cross-informant comparative tables were constructed to identify patterns of convergence and divergence across informants. In Stage 3 (conclusion drawing and verification), interpretive claims were subjected to four triangulation strategies: source triangulation (eight informants across three generations and two genders), method triangulation (observation, interviews, and FGD), member checking (interim findings presented to informants for confirmation or correction), and peer debriefing (analytic interpretations reviewed by an uninvolved colleague). These procedures collectively support the trustworthiness and credibility of the findings(Lincoln & Guba, 1985)

3. FINDINGS AND DISCUSSION

3.1 Findings

3.1.1 The Four Components of Galela Ethroastronomy

Analysis of twenty-four interview transcripts, twelve sets of field notes, and the FGD record produced four principal ethroastronomical components, each confirmed by at least three informants and validated through member-checking. Table 2 presents these components alongside their key scientific correlates and curriculum alignment.

Table 2. Components of Galela Ethroastronomy and Alignment with Junior Secondary Science

No.	Component	Key Scientific Concept	Curriculum Alignment
1	Pariama star (Pleiades): fish movement indicator	Stellar motion; seasonal oceanographic currents	Grade VII: Solar system
2	Ngo-osa full moon: optimal fishing time	Lunar phases; tidal effects; phototaxis	Grade VII: Lunar phases
3	Tiga Bintang Pengikut (Orion's Belt): monsoon indicator	Monsoon cycles; fish migration	Grade VII: Weather and climate
4	Ethro-meteorology: sea condition prediction	Cloud types; wind patterns	Grade VII: Weather phenomena

3.1.2 The Pariama System

The Pariama star system was documented with striking consistency across five informants spanning three generations. Mr. AM (88), the community's senior knowledge custodian, captured its navigational logic concisely:

> *"The Pariama Star has become the main sign for fishermen here. If it goes down to the south, we usually postpone fishing — that indicates there are no fish around here. Beside Pariama, there are also three stars following behind him. That's a sign that the west wind is coming, and after the west wind passes, there are usually a lot of skipjack tuna."*

Critically, this knowledge has not been rendered obsolete by modern technology. Mr. FT (48), who actively uses GPS, confirmed: *"GPS helps with positioning, but when it comes to whether there are many fish or not, we still use natural signs like the west wind and that star."* The apparent seasonal movement of the Pleiades corresponds precisely to Earth's orbital position and the resulting shifts in oceanic currents governing skipjack distribution in Halmahera waters.

a. Ngo-osa: An Indigenous Lunar Calendar

The full moon phase termed *Ngo-osa* functions as the primary temporal organiser for fishing activity. A gender-specific finding emerged distinctively from this component: ecological knowledge absent from all male accounts was documented exclusively from the female informant. Ms. SR (44) described a deeper layer of knowledge centred on lunar phototaxis:

"When it enters Ngo-osa, the anchovies usually rise to the surface. They like light, so they follow the moonlight. If it's very bright, the anchovies gather at the surface, in the areas that are illuminated."

This reveals that beyond tidal effects, the full moon influences the phototactic behaviour of anchovies (*Stolephorus* spp.) a domain of ecological knowledge held exclusively by female community members, with direct implications for research methodology in this field.

b. Three Star Followers: Stellar Ecology for Marine Resource Management

Mr. YB (72) articulated a temporally precise relationship between stellar position and seasonal fish arrival:

"If the three stars' position is already low in the western sky around nine o'clock, it is a sign that the west wind will come. From our experience, about two weeks after that, the skipjack tuna starts to become abundant."

The two-week lead time was independently corroborated by three informants in the FGD. These stars correspond to Orion's Belt (Mintaka, Alnilam, Alnitak), whose seasonal visibility aligns precisely with the onset of the Australian-Asian monsoon governing skipjack migration in Maluku waters.

c. Ethro-Meteorology: An Integrated Prediction System

Mr. HR (65) described a multi-cue atmospheric assessment framework integrating sunset colour, cloud morphology, and wind direction as an integrated decision system for determining safe departure. Uniquely, a gender-specific contribution emerged here as well: Ms. SR documented knowledge entirely absent from male informants the appearance of lenticular clouds above Mount Gamkonora as an indicator of sudden weather deterioration. Teacher BL (Informant 8) directly correlated this observation with cumulonimbus dynamics and land-sea wind patterns addressed in Grade VII KD 3.8, confirming the scientific validity of this female-held ecological knowledge.

3.1.3 Cross-Generational Knowledge Erosion

A systematic cross-generational analysis revealed a worrying pattern of knowledge erosion, summarised in Table 3.

Table 3. Cross-Generational Comparison of Ethroastronomical Knowledge

Component	Senior (65–88 yrs)	Middle (44–48 yrs)	Younger (35 yrs)
Pariama (Pleiades)	Comprehensive; full transmission history	Detailed; integrated with GPS	Name known; meaning unclear
Ngo-osa lunar phase	Comprehensive; full ecological correlates	Detailed; actively applied	Basic concept only
Tiga Bintang (Orion)	Comprehensive + quantitative prediction	Applied; reduced detail	Name known; rarely used
Ethro-meteorology	Holistic: stars + clouds + wind + sun	Partial integration	Basic principles only
Technology relationship	Exclusive reliance on ethroastronomy	GPS and ethroastronomy parallel	GPS dominant

As one middle-generation informant observed: *"Our elders knew everything about the stars from their names, positions, to their meanings for seasons and fish. Most young people nowadays don't pay much attention to the stars anymore. That old knowledge is starting to diminish."* This erosion reflects not the inadequacy of indigenous knowledge itself, but the absence of a formal transmission mechanism precisely the gap that science curriculum integration can address.

3.1.4 The Galela Ethroastronomy Integration Model (MIE-Galela)

Drawing on the four components documented and the cross-generational erosion pattern identified, this study developed the Galela Ethroastronomy Integration Model (MIE-Galela) a four-phase cyclical model for embedding indigenous astronomical knowledge within epistemically just multicultural science learning (Figure 1; Table 4).

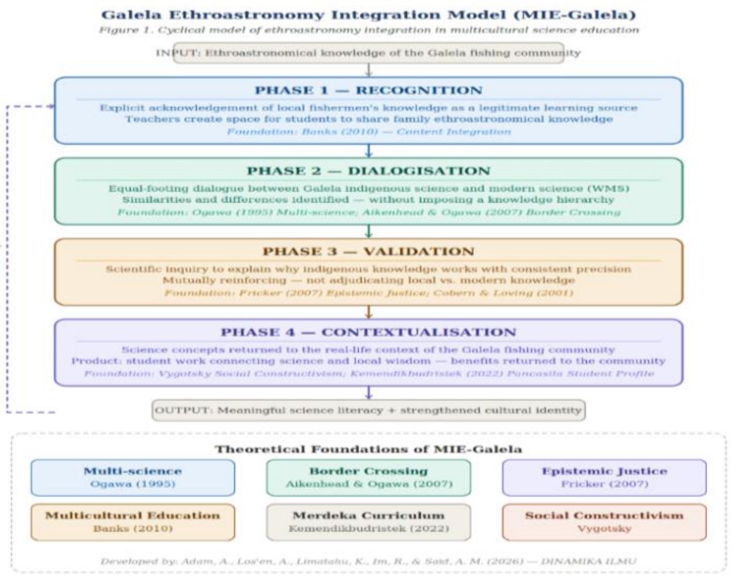

Figure 1. MIE-Galela: A Four-Phase Cyclical Model for Integrating Galela Ethroastronomy into Epistemically Just Multicultural Science Learning

The model operates as a continuous cycle moving from Recognition through Dialogisation, Validation, and Contextualisation, with each phase grounded in distinct theoretical foundations. Input: ethroastronomical knowledge of the Galela fishing community; Output: meaningful science literacy and strengthened cultural identity.

Table 4. MIE-Galela: Phase Descriptions and Classroom Activities

Phase	Name	Core Activity	Learning Indicator
1	Recognition	Teacher acknowledges local knowledge as legitimate; students document family ethroastronomical knowledge	Students identify at least two local astronomical knowledge elements
2	Dialogisation	Equal-footing dialogue between Galela indigenous science and WMS; similarities and differences surfaced without hierarchy	Students construct a Galela science vs. WMS comparison table
3	Validation	Scientific inquiry into *why* indigenous knowledge works with consistent precision — not whether it is correct	Students explain the scientific mechanism underlying at least two ethroastronomical components
4	Contextualisation	Science concepts returned to the fishing community context; knowledge benefits explicitly returned to community	Students produce a Galela Fishermen's Star Map integrating local and scientific nomenclature

3.2 Discussion

The findings demonstrate that the ethnoastronomical knowledge of the Galela fishing community constitutes a coherent indigenous knowledge system developed through long-term interaction with the maritime environment rather than a collection of isolated traditional beliefs. The four principal components identified in this study—stellar navigation, the lunar fishing calendar, monsoon prediction, and ethno-meteorological observation—illustrate how empirical observations of celestial and environmental phenomena have been transformed into practical decision-making systems for navigation, fishing, and weather prediction. This finding supports previous studies arguing that indigenous astronomical knowledge represents systematic empirical knowledge accumulated through repeated observation and environmental adaptation rather than non-scientific folklore (Aikenhead & Ogawa, 2007; Sulaiman et al., 2023). Unlike previous ethnoscience studies in Indonesia that primarily documented isolated astronomical traditions among the Bugis, Javanese, or Balinese communities (Aisyah & Syam, 2024; Sarini & Selamet, 2019), this study demonstrates that Galela fishermen integrate astronomical, ecological, and meteorological observations into a single adaptive knowledge system. Such integration reflects a systems-thinking perspective in which multiple environmental indicators are interpreted simultaneously to support sustainable marine resource management and safe navigation.

A second important finding concerns the significant erosion of ethnoastronomical knowledge across generations. While senior fishermen retained comprehensive understanding of stellar positions, seasonal cycles, ecological indicators, and their practical implications, younger fishermen demonstrated only partial recognition of local astronomical terminology and relied predominantly on Global Positioning System (GPS) technology for navigation. This pattern indicates that indigenous knowledge is not disappearing because it has lost practical value but because traditional mechanisms of intergenerational transmission have weakened. Similar patterns have been reported internationally, where rapid technological development, formal schooling, and socio-economic transformation have contributed to the gradual decline of indigenous ecological knowledge (Norris & Hamacher, 2013). In the Galela context, technological innovation has altered how fishermen obtain navigational information, reducing opportunities for younger generations to learn directly from experienced elders. Consequently, the principal challenge lies not in preserving obsolete traditions but in creating educational mechanisms capable of maintaining valuable indigenous knowledge alongside modern scientific understanding. This finding reinforces the argument that integrating indigenous knowledge into formal education represents an important strategy for cultural sustainability rather than merely curriculum enrichment.

One of the most original findings of this study is the identification of gender-specific domains within Galela ethnoastronomy. Ecological knowledge concerning the phototactic behavior of anchovies during the *Ngo-osa* lunar phase and the interpretation of lenticular clouds above Mount Gamkonora emerged exclusively from female informants and was absent from male narratives. This finding demonstrates that indigenous environmental knowledge is socially distributed according to community roles and experiences rather than uniformly shared among all knowledge holders. Existing ethnoscience studies frequently rely almost exclusively on male informants, particularly in fishing communities, thereby overlooking substantial bodies of ecological knowledge maintained by women. Consequently, this study extends previous research by showing that gender is not merely a demographic characteristic but an epistemological variable influencing the diversity and completeness of indigenous knowledge documentation. The findings therefore suggest that future ethnographic and ethnoscience research should deliberately include female knowledge holders to avoid reproducing epistemic exclusion and to achieve a more comprehensive understanding of community knowledge systems.

The development of the MIE-Galela model represents the principal theoretical contribution of this study. Existing ethnoscience integration frameworks have generally emphasized cultural relevance, conceptual bridging, or inquiry-based learning as mechanisms for integrating indigenous knowledge into science education (Aikenhead, 2001; Cobern & Loving, 2001; Oviana et al., 2025). However, these models primarily focus on comparing indigenous knowledge with Western Modern Science without explicitly addressing unequal epistemic relationships between the two knowledge traditions. MIE-

Galela extends this literature by introducing four interconnected phases—Recognition, Dialogisation, Validation, and Contextualisation—that position indigenous knowledge as an equal epistemic partner in science learning. Rather than treating local knowledge as a preliminary step toward scientific concepts, the model encourages reciprocal dialogue in which students critically examine relationships between indigenous observations and scientific explanations while respecting the integrity of both knowledge systems. Accordingly, multicultural science education becomes a process of knowledge dialogue rather than cultural assimilation.

The Validation phase distinguishes MIE-Galela from previous ethnoscience integration models and constitutes its most significant conceptual innovation. Conventional science classrooms often frame indigenous knowledge through questions such as, "Is this traditional knowledge scientifically correct?" This framing implicitly positions Western science as the sole authority for determining knowledge legitimacy. In contrast, MIE-Galela reframes classroom inquiry toward the question, "Why has this knowledge functioned consistently across generations?" This shift operationalizes Fricker's (2007) concept of epistemic justice by recognizing indigenous communities as credible producers of knowledge rather than merely subjects whose claims require external validation. Testimonial injustice is reduced because students acknowledge indigenous knowledge holders as reliable epistemic agents, while hermeneutical injustice is addressed by incorporating community experiences into formal scientific inquiry. Consequently, epistemic justice is translated from an abstract philosophical concept into a practical pedagogical strategy capable of guiding classroom investigation and scientific reasoning.

The findings also have important implications for the implementation of Indonesia's Merdeka Curriculum. The curriculum emphasizes contextual learning, cultural diversity, inquiry-based pedagogy, and the development of learners who appreciate Indonesia's pluralistic heritage. MIE-Galela aligns closely with these objectives by connecting local maritime knowledge with concepts such as astronomy, lunar phases, weather systems, ecosystems, and scientific investigation. More importantly, the model enables students to understand science through authentic phenomena familiar within their own communities, thereby strengthening both scientific literacy and cultural identity simultaneously. This contextualization supports previous arguments that meaningful science learning occurs when students are encouraged to connect scientific concepts with their everyday experiences and cultural environments (Banks & Banks, 2010). For teachers, the model provides a practical framework for designing inquiry-based lessons that integrate indigenous knowledge without reducing it to anecdotal cultural content.

Overall, this study contributes to the growing international discourse on multicultural science education by demonstrating that indigenous knowledge integration should extend beyond cultural representation toward epistemic transformation. The Galela ethnoastronomical system illustrates that indigenous knowledge possesses empirical coherence, ecological relevance, and educational value capable of enriching science learning when positioned within equitable pedagogical relationships. Through MIE-Galela, this study proposes that science education should not simply teach students about indigenous knowledge but should enable them to investigate how diverse knowledge systems generate valid understandings of the natural world. Such an approach strengthens scientific literacy while simultaneously promoting cultural sustainability, educational inclusion, and epistemic justice within increasingly diverse educational contexts.

4. CONCLUSION

This study demonstrates that the Galela fishing community possesses a sophisticated ethnoastronomical knowledge system comprising four interconnected components—stellar navigation, a lunar fishing calendar, monsoon prediction, and ethno-meteorological observation—that collectively function as a coherent empirical framework for maritime decision-making and environmental adaptation. The findings further reveal a significant pattern of cross-generational knowledge erosion and identify gender-specific ecological knowledge held by female community members, highlighting the importance of inclusive documentation in indigenous knowledge research. Building upon these findings, the study proposes the MIE-Galela model as an innovative framework for integrating indigenous ethnoastronomy into junior secondary science education through four sequential phases: Recognition, Dialogisation, Validation, and Contextualisation. The model advances multicultural science education by operationalising epistemic justice as a practical pedagogical principle, positioning indigenous knowledge as a legitimate epistemic partner rather than merely a cultural supplement to Western science. Nevertheless, this study has several limitations. It was conducted within a single fishing community in North Halmahera, limiting the transferability of the findings to other indigenous maritime contexts. In addition, MIE-Galela remains a conceptual instructional model that has not yet been empirically implemented or evaluated in classroom settings, while the limited number of female knowledge holders participating in the study may not fully represent the diversity of women's ecological knowledge within the community. Future research should therefore examine the effectiveness of MIE-Galela through design-based research or experimental classroom implementation, conduct comparative studies across diverse indigenous maritime communities in Indonesia and other Austronesian regions, and further investigate the role of gender in the production, transmission, and educational integration of indigenous ecological knowledge to strengthen culturally responsive and epistemically just science education.

REFERENCES

Adam, A., & Soleman, N. (2022). The portrait of Islamic education online learning during the COVID-19 pandemic in MAN 1 Ternate. *Didaktika Religia: Journal of Islamic Education, 10*(2), 295–314. https://doi.org/10.30762/didaktika.v10i2.3333

Aikenhead, G. S. (2001). Students' ease in crossing cultural borders into school science. *Science Education*, *85*(2), 180–188. https://doi.org/https://doi.org/10.1002/1098-237X(200103)85:2<180::AID-SCE50>3.0.CO;2-1

Aikenhead, G. S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education*, *2*(3), 539–620. https://doi.org/10.1007/s11422-007-9067-8

Aisyah, N., & Hikmatul Adhiyah Syam. (2024). Integrasi Navigasi dan Rasi Bintang (Tradisi Astronomi Masyarakat Etnis Sulawesi). *ELFALAKY: JURNAL ILMU FALAK*, *8*(2), 231–256. https://doi.org/https://doi.org/10.24252/ifk.v8i2.51279

Banks, J. A., & Banks, C. A. M. (2010). *Multicultural education: Issues and perspectives*. John Wiley & Sons.

Cobern, W. W., & Loving, C. C. (2001). Defining "science" in a multicultural world: Implications for science education. *Science Education*, *85*(1), 50–67. https://doi.org/https://doi.org/10.1002/1098-237X(200101)85:1<50::AID-SCE5>3.0.CO;2-G

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Dierking, L. D., Falk, J. H., Coeditors, S., & Medin, D. (2010). Cultural Processes in Science Education : Supporting the. *ScienceEducation*. https://doi.org/10.1002/sce.20392

FARICHA, F. (2023). Etnoastronomi Masyarakat Samin. *Eprints.Walisongo.Ac.Id*. https://eprints.walisongo.ac.id/25151/1/Disertasi_1600039004_Faiz_Faricha.pdf

Fricker, M. (2007). *Epistemic injustice: Power and the ethics of knowing*. Oxford university press. https://doi.org/0198237901

Lewis, D. (1978). *The Voyaging Stars: Secrets of the Pacific Island Navigators*. Collins. https://books.google.co.id/books?id=T1CBAAAAMAAJ

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry; Sage Publications: Newbury Park*. CA USA.

Menteri Pendidikan Kebudayaan Riset dan Teknologi Republik Indonesia. (2022). *Salinan Keputusan Menteri Pendidikan, Kebudayaan, Riset dan Teknologi Republik Indonesia Nomor 56/M/2022 tentang Pedoman Penerapan Kurikulum dalam Rangka Pemulihan Pembelajaran*. 112.

Norris, R. P., & Hamacher, D. W. (2013). Australian Aboriginal Astronomy: Overview. *ArXiv Preprint ArXiv:1306.0971*.

Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education*, *79*(5), 583–593. https://doi.org/10.1002/sce.3730790507

Oviana, W., Jannah, M., Nurdin, S., & Rahmi, P. (2025). The Implementation of an Ethno-Inquiry-Based Science Module to Enhance the Scientific Process Skills of Prospective Primary School Teachers. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *10*(1), 275–286. https://doi.org/ https://doi.org/10.24042/tadris.v10i1.26719

Sarini, P., & Selamet, K. (2019). Pengembangan Bahan Ajar Etnosains Bali bagi Calon Guru IPA. *Jurnal Matematika,Sains, Dan Pembelajarannya*, *13*(1), 27–39. https://doi.org/https://doi.org/ 10.23887/ wms.v13i1.17146

Sulaiman, N. A. A., Hassan, S. A., Shaffril, H. A. M., & Hanapi, M. S. (2023). Fishermen's Knowledge of Astronomical Phenomena in Fishery Activities: A Systematic Literature Review. *Pertanika Journal of Social Sciences and Humanities*, *31*(1), 1–24. https://doi.org/10.47836/PJSSH.31.1.01

Urton, G. (1981). *At the Crossroads of the Earth and the Sky: An Andean Cosmology*. University of Texas Press. https://books.google.co.in/books?id=jWJsAAAAMAAJ

Wiyanarti, E., & Holilah, M. (2018). Utilizing Nautical Tradition Value Through Ethnoastronomy in Learning Social Science. *Atlantis Press*, *147*(Icsse 2017), 98–101. https://doi.org/10.2991/icsse-17.2018.23