Strengthening prospective mathematics teachers' geometry understanding through ethnomathematics integrated with generative artificial intelligence

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Abstract

This study aims to strengthen prospective mathematics teachers' geometry understanding through ethnomathematics-based learning grounded in Papuan traditional houses integrated with Generative Artificial Intelligence (GenAI). A mixed-methods case study design with embedded quantitative data was employed involving 32 prospective teachers. Data were collected through geometry comprehension tests, ethnomathematical analysis rubrics, questionnaires, interviews, and observations, and analysed using descriptive statistics and thematic coding. The results show a significant increase in students' mean scores from 58 to 80, alongside improved ability to connect geometric concepts with cultural structures. GenAI facilitated visualization, conceptual validation, and reflective thinking. This study contributes to the integration of ethnomathematics and generative technology as a culturally responsive and pedagogically meaningful approach in geometry education.

Keywords: ethnomathematics, GenAI, geometry, Papuan traditional houses, prospective mathematics teachers

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INTRODUCTION

Geometry learning in mathematics education is still often perceived as an abstract, symbolic, and separate field of study from the concrete experience of students, especially at the level of education of prospective mathematics teachers. This condition causes geometry to be one of the most challenging materials both in terms of conceptual understanding and pedagogical application. Mastery of definitions, theorems, and formulas alone is not enough to build a meaningful and sustainable understanding of geometry; prospective teachers also need spatial reasoning, mathematical communication, and pedagogical readiness to connect formal ideas with real learning situations (Prachagool et al., 2022; Sudana et al., 2024). Therefore, strengthening the understanding of geometry in prospective mathematics teachers is a fundamental need that demands learning approaches oriented not only to formal mathematical structures, but also to real experiences and relevant contexts.

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In this context, ethnomathematics emerged as a promising approach because it placed mathematics as a product of human cultural activity, rather than simply an abstract construct detached from social reality. Ethnomathematics allows learners to build mathematical meaning through cultural practices that they are familiar with or that are close to people's lives. Various studies confirm that local cultural artifacts, such as traditional houses and traditional architecture, contain rich and authentic mathematical concepts (Fauzi et al., 2022; Hendriyanto et al., 2023). Traditional houses not only represent cultural identity and values but also contain geometric structures such as symmetry, proportionality, transformation, and complex spatial relationships. Ethnomathematical studies in various regions of the archipelago show that the exploration of traditional houses as a learning context is able to bridge the gap between formal geometry and the concrete experiences of students (Ratau et al., 2025; Widodo et al., 2024).

Theoretically, ethnomathematics has a strong alignment with the principles of Realistic Mathematics Education (RME), which emphasizes the importance of real context as a starting point for learning mathematics. RME views mathematics as a human activity that develops through the process of mathematization from contextual situations to formal representations. Research shows that local cultural practices, including those found in Sasak culture and traditional house architecture, have conceptual correspondence with RME characteristics, particularly in the use of cultural artifacts as a starting situation for learning (Fauzi et al., 2022). Studies on traditional houses and cultural motifs also reveal geometric relationships involving spatial geometry, measurement, symmetry, tessellation, and ratio (Fitriza et al., 2018; Haryanto et al., 2016; Widodo et al., 2024).

Nonetheless, the challenge of learning geometry lies not only in the selection of context but also in how learners construct adequate visual representations and spatial reasoning. Geometry demands the ability to visualize, exercise spatial imagination, and connect two- and three-dimensional representations. In this case, the development of educational technology opens new opportunities to strengthen geometry learning. The integration of digital technologies, especially Generative Artificial Intelligence (GenAI), offers significant potential in supporting visualization, exploration, and reflection of mathematical concepts. GenAI, including large language model-based chatbots, can act as a cognitive partner that helps learners articulate understanding, ask reflective questions, and identify misconceptions, although its use also requires critical control due to potential misinformation and academic integrity risks (Abd-Alrazaq et al., 2023; Clark et al., 2023; Tyson, 2023).

In the education of prospective mathematics teachers, the integration of technologies such as GenAI needs to be positioned not only as a technical aid but also as part of the development of pedagogical and reflective competencies. Strengthening the geometry understanding of prospective teachers is a multidimensional process that includes conceptual mastery, mathematical communication, digital literacy, and pedagogical readiness (Liana et al., 2024; Prachagool et al., 2022; Sudana et al., 2024). Studies on learning management systems and digital media show that technology can support the visualization and exploration of concepts more effectively when designed with an appropriate pedagogical framework (Rizal et al., 2022). However, without meaningful cultural context, technology may merely reproduce abstract learning in digital form.

In the context of multicultural Indonesia, Papuan traditional houses offer great potential as a source of ethnomathematics that has not been explored in depth in geometry learning. Papuan traditional houses not only have architectural uniqueness but also reflect spatial relationships, geometric structures, and rich cultural values. Previous studies on Biak-Papua cultural artifacts, Rumah Kaki Seribu, and Honai construction indicate that Papuan architecture contains mathematical ideas such as symmetry, proportion, circularity, spatial structure, and measurement practices (Haryanto et al., 2016; Kho et al., 2025; Rumah et al., 2018). However, research that integrates Papuan ethnomathematics with GenAI technology in the context of prospective mathematics teacher education remains limited.

Based on this gap, this study offers novelty in integrating the ethnomathematics of Papuan traditional houses with GenAI as a mediator of geometry learning for prospective mathematics teachers. The novelty of this research lies in the use of GenAI not as a provider of instant answers, but as a tool for visual exploration, conceptual analysis, and mathematical reflection based on cultural contexts. This position is consistent with recent arguments that GenAI should be used as a guided scaffold rather than an autonomous knowledge authority in education (Abd-

Alrazaq et al., 2023; Tyson, 2023). In terms of originality, this research combines three domains that are rarely met simultaneously, namely Papuan ethnomathematics, geometry learning for prospective teachers, and generative technology.

In line with this presentation, this research aims to strengthen the conceptual understanding of geometry of prospective mathematics teachers through ethnomathematics-based learning of Papuan traditional houses integrated with GenAI. In particular, this study explores how Papuan traditional house artifacts can function as conceptual sources of geometry and how GenAI can support visualization, analysis, and mathematical reflection in these contexts. This study also examines how prospective teachers interpret geometry learning experiences that combine local cultural contexts and generative technologies in relation to their pedagogical readiness. Based on the synthesis of literature that has been presented, the formulation of this research problem is focused on how genAI-integrated, ethnomathematics-based geometry learning of Papuan traditional houses can strengthen the conceptual understanding of geometry of prospective mathematics teachers. The formulation of this problem is designed to answer the theoretical and practical needs in the development of contextual, reflective, and future-oriented geometry learning (Pasaribu et al., 2025), (Suhartik et al., 2025).

While previous studies have explored ethnomathematics in traditional architecture and the use of digital technologies in mathematics education separately, few studies have explicitly integrated Papuan ethnomathematics with generative artificial intelligence in the context of prospective teacher education. Existing research (e.g., Fauzi et al., 2022; Widodo et al., 2024) primarily focuses on cultural exploration without technological mediation, while studies on GenAI (Abd-Alrazaq et al., 2023) emphasize its role as a cognitive tool without contextual cultural grounding. Therefore, this study addresses a specific gap by combining (1) underexplored Papuan cultural contexts, (2) geometry conceptualization, and (3) GenAI as a reflective cognitive partner. This integrative approach represents a novel contribution by positioning GenAI within culturally responsive mathematics learning rather than as a standalone technological tool.

METHODS

This study employed a mixed-methods design, specifically an embedded case study, where qualitative data were dominant and supported by quantitative measures. The qualitative approach was chosen because this research aims to deeply understand the learning process, the construction of conceptual understanding of geometry, and the reflective experiences of prospective mathematics teachers in the context of local culture. The research design focuses on the implementation of ethnomathematics-based geometry learning of Papuan traditional houses that are developed and applied in real lecture situations. Learning is designed in line with the principles of Realistic Mathematics Education (RME), which places the cultural context as the starting point for progressive mathematics (Fauzi et al., 2021). GenAI is integrated as a tool for exploration and conceptual reflection, rather than as a source of final answers, by applying the human-in-the-loop principle as recommended in the study of the use of generative technology in education (Clark et al., 2023), (Tyson, 2023). With this design, the research not only evaluates learning outcomes, but also examines the dynamics of the learning process holistically.

The research subjects consisted of 32 students who were prospective middle semester mathematics teachers in the Mathematics Education Study Program at educational universities, as well as 1 lecturer in the Geometry course who acted as a learning facilitator. The selection of subjects was carried out purposively by considering the active involvement of students in geometry lectures and openness to learning based on cultural context and digital technology. Students have diverse academic backgrounds and most have never participated in formal ethnomathematics learning or used GenAI in the context of geometry learning. The research setting takes place in regular lectures designed on a project-based basis, where students in groups explore the concept of geometry contained in Papuan traditional houses. The learning environment includes classroom discussions, analysis of visual artifacts of traditional houses, guided interaction with GenAI, as well as pedagogical reflections. This context was chosen to ensure a direct link between learning, local culture, and the competency development of prospective teachers (Rumah et al., 2018).

The research instruments included a contextual geometry comprehension test, an ethnomathematical analysis rubric, a questionnaire on the perception of the use of GenAI, and reflective interview guidelines. The geometry comprehension test was used to identify changes in students' conceptual understanding of geometric concepts associated with Papuan traditional houses. The ethnomathematical analysis rubric is designed to assess students' ability to identify and explain geometric concepts in cultural artifacts in a systematic manner. The perception questionnaire was used to explore students' views on the role of GenAI in supporting mathematical visualization and reflection. Reflective interviews were conducted to obtain in-depth data on learning experiences, difficulties, and pedagogical meanings that students built during the learning process. All instruments were developed in line with the research objectives and the context of culture and technology-based learning.

The data collection procedure is carried out through several stages that are mutually continuous. The initial stage includes the exploration of Papuan traditional houses through visual materials and contextual discussions to identify potential geometric concepts. The next stage is the analysis and visualization of geometric concepts with the help of GenAI, where students interact in a guided manner to ask conceptual questions and reflect on their findings. Next, students compile ethnomathematics-based geometry learning projects and present the results. Data was collected through learning observations, test results, questionnaires, interviews, and documentation of student activities. Data analysis is carried out qualitatively through the stages of data reduction, data presentation, and conclusion drawn, emphasizing consistency between empirical findings and the theoretical framework used (Haryanto et al., 2016). All instruments were validated through expert judgment involving three mathematics education experts to ensure content and construct validity. The geometry comprehension test was further analysed using item validity and reliability testing, with Cronbach's alpha indicating acceptable internal consistency

RESULTS AND DISCUSSION

Location Conditions and Research Context

This research was carried out in the Mathematics Education Study Program at an educational college in the context of geometry lectures in the middle semester. The lectures last for eight weeks with a time allocation of 3 credits and are designed using a project-based learning approach that integrates ethnomathematics and GenAI. The learning environment includes classrooms, the Learning Management System, and the GenAI platform, which is used as a medium for mathematical exploration and reflection. During the research process, all learning activities were documented through observation notes, student work results, discussion recordings, and screenshots of student interactions with GenAI. The classroom conditions showed a stable level of student attendance and active participation during the implementation of learning. There were no significant administrative or technical interruptions during the data collection process. Thus, the research context can be categorized as conducive to observing the ethnomathematics-based geometry learning process of Papuan traditional houses integrated with GenAI.

Research Informant Profile

The research informants consisted of 32 prospective mathematics teacher students in the fourth semester and 1 lecturer in the Geometry course. Students come from diverse secondary education backgrounds, including high schools majoring in science and vocational schools. Based on preliminary data, most students have never participated in formal ethnomathematics learning and 65% of students stated that they are not used to using GenAI in geometry learning. Student informants are given initials code M1 to M32 to maintain identity confidentiality. The lecturer in charge of the course is given the initials D1. From the results of initial observations, students showed a variety of abilities in understanding geometry concepts, especially building spaces and spatial relations. This condition is the basis for the implementation of ethnomathematics-based learning of Papuan traditional houses with the support of GenAI.

Data Preliminary Study

The results of initial observations show that before the implementation of learning, most students tend to be passive when discussing spatial geometry material. Class discussions were dominated by lecturers' explanations, while students took more notes and waited for instructions. Early diagnostic tests showed that 70% of students were only able to recognize geometric shapes symbolically, without being able to associate them with real objects or cultural contexts. The initial interview revealed the student's statement as follows:

"*We usually learn geometry through formulas and pictures in books, rarely associated with cultures or traditional houses*." (M7)

A similar statement was also made by M14, stating that previous geometry lessons felt "abstract and hard to imagine." This initial data shows the initial condition of students' understanding of geometry before the implementation of GenAI's integrated ethnomathematics-based learning.

Implementation of Learning and Student Activities

During the learning process, students engage in visual exploration of Papuan traditional houses through images, videos, and architectural documentation. Students are asked to identify geometric elements such as flat shapes, spatial shapes, symmetry, and spatial relationships found in traditional house structures. Furthermore, students use GenAI to help visualize geometric shapes, ask conceptual questions, and clarify their identification results. Interactions with GenAI are documented in the form of screenshots, conversations, and student reflection notes. Observations showed that students were more active in discussing and asking questions compared to the initial learning conditions. Group activities are intensive, especially at the stage of geometry analysis and the preparation of learning projects.

Contextual Geometry Comprehension Test Results

Quantitative data were obtained through contextual geometry comprehension tests administered before and after learning. The results showed an increase in the average score of students' geometry understanding from 58 in the initial test to 80 in the final test. Most students showed an improved ability to explain geometric concepts by associating them with the structure of Papuan traditional houses. This increase indicates a shift from symbolic recognition toward contextual and meaningful understanding. In line with ethnomathematics and RME perspectives, the cultural context served as a bridge between informal experience and formal geometric representation (Fauzi et al., 2022; Hendriyanto et al., 2023).

Results of Qualitative Data Analysis

Qualitative data were obtained from reflective interviews, perception questionnaires, and learning documentation. The results of the interviews showed that students were able to explain geometric concepts narratively by referring to Papuan traditional houses. For example, M12 states:

"*The roof of a traditional house can be explained as a combination of several spatial buildings, and I understand better because I can imagine the shape.*"

Another student, M21, said:

"*With the help of GenAI, I was able to confirm whether the geometry concepts I found were correct or not.*"

The assignment documentation shows that students were able to systematically compile ethnomathematical analyses of traditional houses using the rubrics provided. The perception questionnaire showed that most students rated the use of GenAI as helpful for understanding complex geometric shapes and clarifying spatial visualizations. These findings indicate that GenAI functioned as a cognitive scaffold for visualization, conceptual checking, and reflection, rather than as a substitute for students' reasoning. This result is consistent with the view that GenAI can support learning when interaction is guided by clear pedagogical purposes and critical verification (Abd-Alrazaq et al., 2023; Clark et al., 2023; Tyson, 2023).

Key Research Findings

Based on the data presentation, the main findings of this study cover three integrated themes: (1) Papuan traditional houses function as authentic sources of geometry concepts, (2) GenAI supports visualization and exploration of geometry concepts, and (3) learning encourages pedagogical awareness of prospective mathematics teachers. These themes appeared consistently across observation data, test results, interviews, and learning documentation. The findings strengthen previous ethnomathematics studies by showing that cultural artifacts are not merely contextual illustrations, but conceptual resources that can be transformed into meaningful geometry learning (Haryanto et al., 2016; Kho et al., 2025; Ratau et al., 2025).

Participant Reflection and Evaluation

Students' reflections show a positive response to the learning applied. One of the students stated:

"*Geometry comes alive because it's close to culture, and GenAI helps me understand shapes that are hard to imagine.*" (M3)

The lecturer in charge of the course (D1) also said that students seemed more active and able to explain geometry concepts in a more contextual way compared to previous lectures. This reflection indicates that the project-based activities supported student engagement, collaborative reasoning, and pedagogical awareness. For prospective mathematics teachers, these experiences are important because they model how culture and technology can be combined responsibly in future classroom practice (Liana et al., 2024; Rizal et al., 2022).

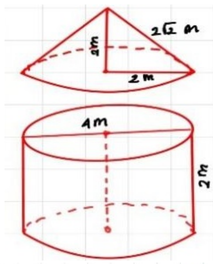
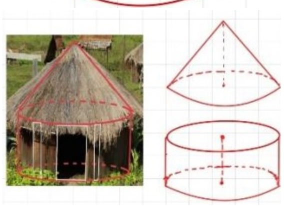
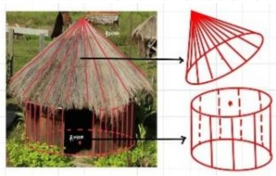
Findings of Drawings/Sketches Of Mathematical

All of these findings have been systematically arranged based on their respective categories and presented in the following tables. The tables do not only summarize the identified geometric concepts, but also demonstrate how Papuan traditional houses can be interpreted as conceptual sources for geometry learning. Therefore, the visual and mathematical representations below are part of the integrated result-and-discussion narrative rather than separate descriptive findings.

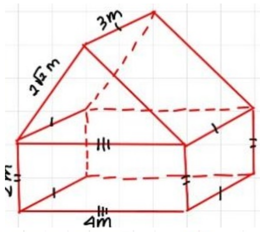
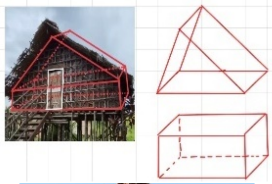
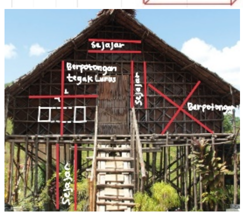
Table 1. Key Geometry Concepts

House	Key Geometry Concepts	Representation
Honai	Cylinder, Cone, Circular symmetry	Roof & base
Rumah Kaki Seribu	Prism, Cuboid, Triangle	Structure & stairs
Rumah Pohon	Cube, Height proportion	Vertical structure

Table 2. Data Analysis Results

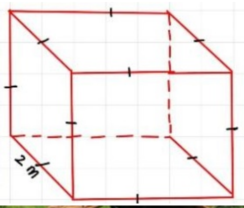
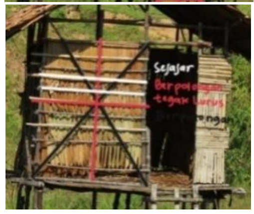
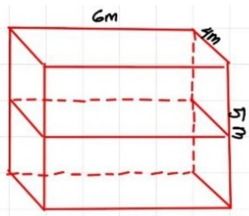
No.	Aspects of Findings	Description	Drawings/Sketches of Mathematical
		Honai House	
1.	a) a) Background of the house	a) Honai House is a traditional house of the Dani tribe from the Baliem Valley, Papua. Built according to the cold climate of the highlands.	
	b) Function of the house.	As a residence for adult men and a center for customary discussion	-
	c) Philosophical	Symbolizes warmth, unity and family.	-
	d) House structure	Circular in shape with wooden walls and a conical roof made of straw.	-
	e) Materials:	Local wood, bamboo and straw.	-
	f) Measurement techniques	Using body measurements (height, footsteps).	-
	g) The size of the house	Is 4 meters in diameter and 4 meters high.	
	h) Geometric elements	Circular base, cylindrical base, and conical roof.	
	i) Symmetry pattern	Infinite rotational symmetry in the shape of a cylindrical circle.	

2) **Rumah Kaki Seribu**

a)	a) Background of the house	Typical stilt houses of the Arfak tribe in the Arfak Mountains, Manokwari.	
b)	Function of the house.	A dwelling that is resistant to floods and wild animals.	-
c)	Philosophical	Symbolizes strength and protection.	-
d)	House structure	Rectangular in shape with wooden pillars with a leaf roof.	-
e)	Materials:	Wood, bamboo, rattan, and leaves.	-
f)	Measurement techniques	Using the length of the wood and the stride of the foot.	-
g)	The size of the house	4 meters long, 3 meters wide and 5 meters high.	
h)	Geometric elements	The rectangular base forms a block, the triangular roof forms a triangular prism, and the stairs form a right triangle.	
i)	Symmetry pattern	The rectangular base forms a block, the triangular roof forms a triangular prism, and the stairs form a right triangle.	

3) **Rumah Pohon**

a)	a) Background of the house	The traditional house of the Korowai tribe is built high in the trees.	
b)	Function of the house.	The traditional house of the Korowai tribe is built high in the trees.	-
c)	Philosophical	A symbol of the close relationship between humans and nature and resilience.	-
d)	House structure	A stilt house 8-12 meters high with tree trunks as the main foundation.	-
e)	Materials:	Wood, rattan, and dry leaves.	-
f)	Measurement techniques	Using tree height or wood length.	-

g)	The size of the house	Length and width 2 meters, height 5 meters.	
h)	Geometric elements	The square base forms a cube, the triangular roof forms a triangular prism.	
i)	Symmetry pattern	Reflection symmetry in wall design.	
4)		**Rumah Rumsram**	
a)	a) Background of the house	The traditional house of the Biak tribe is inspired by the shape of a boat.	
b)	Function of the house.	A place for young people to study and discuss.	-
c)	Philosophical	Symbolizes maritime tribal identity, a symbol of knowledge and education.	-
d)	House structure	Rectangular in shape with a steep roof like an upside-down boat.	-
e)	Materials:	Coconut wood, rattan, and dry leaves.	-
f)	Measurement techniques	Based on the length of the wood and adjusted to the size of the boat.	-
g)	The size of the house	Length 6 meters, width 4 meters, height 5 meters.	
h)	Geometric elements	The rectangular base forms the beam and the roof is trapezoidal.	
i)	Symmetry pattern	Reflective symmetry in wall and door design.	

Synthesis of Integrated Findings

The integrated findings indicate that GenAI-assisted ethnomathematics learning strengthened prospective mathematics teachers' geometry understanding through three mutually reinforcing mechanisms. First, Papuan traditional houses provided authentic cultural objects that helped students interpret abstract geometric concepts through concrete structures. Second, GenAI supported visualization, comparison, and conceptual verification during the learning process. Third, project-based tasks encouraged students to transform cultural exploration into pedagogical products. These mechanisms explain the increase in students' mean score from 58 to 80 and the richer qualitative explanations found in interviews and assignments (Fauzi et al., 2022; Haryanto et al., 2016; Kho et al., 2025).

The findings also confirm the alignment between ethnomathematics and Realistic Mathematics Education because students began with contextual exploration, identified mathematical relations, and gradually represented them in more formal geometric forms. This learning trajectory reflects progressive mathematization and expands prior studies on traditional architecture by adding GenAI as a reflective mediator in the process (Fauzi et al., 2021; Hendriyanto et al., 2023; Ratau et al., 2025).

Compared with earlier ethnomathematics research that relied mainly on cultural exploration, this study shows that technological mediation can enrich visual and reflective processes when it is carefully guided. However, GenAI did not automatically improve learning; its effectiveness depended on the quality of prompts, lecturer guidance, and students' ability to verify AI-generated responses. This confirms the human-in-the-loop principle and positions GenAI as a scaffold rather than an autonomous source of mathematical truth (Abd-Alrazaq et al., 2023; Clark et al., 2023; Tyson, 2023).

In the context of teacher education, the findings are significant because students not only improved their conceptual understanding of geometry but also developed awareness of how contextual and technology-integrated learning can be designed. The learning experience gave prospective teachers a model for connecting local culture, spatial reasoning, digital literacy, and reflective pedagogy in mathematics classrooms (Liana et al., 2024; Prachagool, 2022; Sudana et al., 2024).

Practically, the study suggests that mathematics education lecturers can use traditional architecture as a meaningful starting point for geometry learning and integrate GenAI through structured prompts, verification tasks, and reflective discussions. Curriculum developers may also consider ethnomathematics and AI literacy as complementary components in preparing future mathematics teachers for culturally responsive and technology-rich learning environments (Assegaff & Bonyah, 2024; Rokhmah et al., 2024).

Limitations of the Findings

Although the integration of Generative Artificial Intelligence (GenAI) supported students' understanding and representation of geometric concepts, this study also identified several limitations. First, the study was conducted in one institutional context with one class of 32 students; therefore, generalization should be made cautiously. Second, limited direct field exploration of Papuan traditional houses reduced the depth of students' empirical cultural experience. Third, several students initially tended to rely excessively on GenAI-generated responses and required lecturer guidance to verify the mathematical accuracy of their interpretations. These limitations indicate that future studies should involve broader samples, longer implementation, direct cultural fieldwork, and stronger preparation in prompt literacy and AI ethics.

CONCLUSION

This study demonstrates that integrating ethnomathematics of Papuan traditional houses with GenAI effectively enhances prospective teachers' geometry understanding. The findings highlight the role of cultural context in making abstract concepts meaningful and the function of GenAI as a cognitive scaffold for visualization and reflection. This study contributes to the development of culturally responsive and technology-integrated mathematics learning. Theoretically, this study extends the framework of ethnomathematics by incorporating generative technology as a mediating cognitive tool. Practically, it provides a model for integrating local culture and AI in teacher education. These implications suggest the need for further exploration of the certain areas to fully realize the potential of integrating ethnomathematics with generative AI in teacher education. Future research should examine how prospective teachers can be trained to define the pedagogical logic such as Socratic questioning which is embedded within AI prompts, and allow the educators to encode cultural and geometric constrains directly into AI feedback system. Besides that, there is pressing need to investigate the cognitive balance between automated guidance and independent mathematical reasoning, whether the integration of generative AI in ethnomathematics fosters or hiders the procedural vs conceptual understanding in prospective teachers.

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