Emergent Geometry in Ikan Keturi Piring: A Generative Ethnomathematical Model of Cultural Cognition

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Abstract. The persistent disconnection between abstract geometry and students lived cultural experience—particularly in Indonesian junior high school contexts—continues to limit meaningful mathematical understanding. Although ethnomathematics has established that mathematical ideas are embedded in cultural practices, existing studies remain largely descriptive and fail to explain how geometric reasoning emerges or how it can be systematically integrated into instruction. Addressing this gap, this study investigates the geometric structures embedded in the cultural practice of *Ikan Keturi Piring*, the mechanisms through which these structures emerge, and their transformation into meaningful geometry learning. Using a qualitative approach with focused ethnography, data were collected through participant observation, semi-structured interviews, and documentation involving 12 participants, including practitioners, cultural elders, and mathematics teachers. The findings indicate that geometric reasoning—reflected in circularity, radial symmetry, proportional spacing, and implicit angular partitioning—emerges through iterative spatial regulation guided by cultural principles of balance and harmony. These results demonstrate that geometry is not merely learned as formal abstraction but constructed as a culturally mediated cognitive process that links cultural activity with mathematical reasoning. Theoretically, this study advances ethnomathematics toward a generative epistemological framework that models the emergence of geometry from the interaction between cultural rules and cognitive constraints. Practically, it provides a pedagogical pathway, such as analyzing circular arrangements and determining central angles (360° divided by the number of elements), to support contextual and embodied learning. This study redefines geometry as a culturally grounded system that transforms how mathematical knowledge is understood and taught.
Keywords: Ethnomathematics, Emergent Geometry, Geometry Learning, Cultural Practice, Spatial Reasoning.

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1. Introduction

Within mathematics education research, a substantial body of empirical evidence has consistently documented students' persistent difficulties in learning geometry, particularly in conceptualizing spatial relationships and transitioning from procedural to conceptual understanding (Maarif, 2015; Nurhikmayati, 2017; Susanti, 2020). These challenges are not merely technical but are structurally rooted in instructional practices that privilege symbolic manipulation over meaning-making. As Boaler (2022) argues, such decontextualized approaches produce fragmented knowledge structures and limit students' capacity to apply mathematical concepts beyond procedural contexts. In many Indonesian classrooms, this issue is further intensified by learning environments that remain detached from students' sociocultural realities, resulting in mathematics being perceived as abstract and irrelevant. This condition reveals a fundamental problem: the disconnection between formal mathematical knowledge and culturally grounded meaning-making processes.

From an epistemological standpoint, this problem reflects a tension between mathematics as a universal, value-neutral system and mathematics as a culturally situated human activity. The dominant paradigm in school mathematics emphasizes abstraction and formalism, often marginalizing learners' experiential knowledge (Barton, 2018). In contrast, ethnomathematics reconceptualizes mathematics as knowledge constructed through cultural practices and social interaction (D'Ambrosio, 1985; Rosa & Orey, 2016). Bishop (1988) further demonstrates that core mathematical activities—such as measuring, designing, and explaining—are inherently embedded in cultural life. Within this perspective, geometry becomes a particularly strategic domain because its visual and spatial characteristics resonate strongly with patterns and structures found in cultural artifacts, making it a powerful bridge between abstract reasoning and lived experience.

Recent studies have reinforced the pedagogical value of integrating culture into mathematics learning. For instance, Rosa and Orey (2021) show that culturally grounded instruction enhances conceptual understanding and student engagement. Similarly, Gay (2018) and Ladson-Billings (2021) argue that culturally responsive pedagogy strengthens students' identity and participation in learning. However, despite these contributions, critical limitations remain. Rosa and Orey (2021), while emphasizing cultural integration, do not provide a domain-specific framework for translating ethnomathematics into geometry learning. Likewise, Sarwoedi et al. (2018) and Zayyadi (2017) successfully identify mathematical elements in cultural practices, yet their analyses remain largely descriptive and do not extend to interpretative or instructional design levels. More recent empirical studies (2022–2024) further indicate that although ethnomathematics improves engagement, its classroom implementation remains fragmented due to the absence of structured pedagogical models. Collectively, these studies reveal a consistent limitation: the lack of an operational framework that connects cultural practices, geometric reasoning, and instructional transformation.

In the Indonesian context, where cultural diversity is extensive, this limitation becomes particularly significant. Cultural practices—including traditional food, crafts, and daily activities—represent rich epistemic resources for mathematical meaning-making. However, most of these practices remain underexplored, and their embedded geometric structures are rarely examined through a systematic and theoretically grounded lens. More importantly, there is limited effort to transform these insights into pedagogically actionable representations. As a result, a critical gap persists across three interconnected dimensions: empirical (limited exploration of local cultural practices), conceptual (lack of systematic geometric analysis), and pedagogical (absence of instructional frameworks).

To address this gap, this study advances a conceptual framework that positions cultural practices as epistemological sources of mathematical meaning-making. Specifically, the study proposes a three-layered relationship: (1) cultural practice as a generative structure, (2) geometric concepts as embedded formal representations, and (3) pedagogical transformation as instructional reconstruction. Within this framework, cultural artifacts are not treated merely as contextual examples, but as epistemic mediators that enable the reconstruction of abstract geometric concepts into meaningful learning experiences.

One cultural practice that exemplifies this framework is Ikan Keturi Piring, a traditional food of the Malay community in Jangkang, Sanggau Regency, West Kalimantan. This practice, familiar to students' daily lives, involves arranging fish in circular formations using culturally transmitted techniques. Such arrangements embody key geometric concepts, including circularity, symmetry, repetition, and proportional relationships. More importantly, this practice provides a concrete epistemic space in which abstract geometric ideas can be interpreted and reconstructed through culturally meaningful experiences.

Methodologically, this study adopts an ethnographic approach to capture the cultural meanings and embedded geometric structures within this practice. This approach is appropriate because it enables an in-depth understanding of how mathematical knowledge is constructed within cultural contexts and how it can be translated into pedagogically meaningful representations.

Positioned within the discourse of ethnomathematics and culturally responsive mathematics education, this study makes four key contributions. First, it contributes empirically by documenting a culturally distinctive and underexplored practice. Second, it contributes conceptually by systematically analyzing geometric structures embedded in cultural contexts. Third, it contributes pedagogically by developing representations that can be integrated into geometry learning. Fourth, and most importantly, it contributes theoretically by proposing a framework that operationalizes the relationship between cultural practice, geometric reasoning, and instructional transformation.

Accordingly, this study aims to analyze the geometric concepts embedded in Ikan Keturi Piring, construct their ethnomathematical representations, and examine their integration into geometry learning at the junior high school level. In this sense, geometry learning is not merely the acquisition of abstract knowledge, but a culturally mediated process of meaning construction.

2. Method

This study employed a focused ethnography within a qualitative paradigm to investigate geometric concepts embedded in the cultural practice of *Ikan Keturi Piring*. Focused ethnography is particularly suitable for examining specific cultural phenomena within a limited time frame while maintaining analytical depth (Knoblauch, 2005; Creswell & Poth, 2018). The design aligns directly with the research objectives, namely identifying embedded geometric structures, interpreting their cultural meanings, and transforming them into pedagogical representations. Unlike general ethnography, this approach enables systematic and replicable observation of a bounded cultural practice.

The researcher assumed the role of a moderate outsider and implemented reflexive strategies to minimize interpretive bias. These included maintaining reflexive journals after each field session, bracketing prior assumptions during the coding process, and conducting peer debriefing at each stage of analysis (Lincoln & Guba, 1985). These procedures ensured transparency and enhanced analytical rigor throughout the research process.

The study was conducted in Jangkang, Sanggau Regency, West Kalimantan, Indonesia, where the cultural practice of *Ikan Keturi Piring* is actively maintained. To ensure replicability, data were collected across three household settings and one communal event, encompassing six observation sessions of two to three hours each over a period of four consecutive weeks. The observations included both routine cooking activities and ceremonial preparations to capture contextual variation. However, it should be noted that the findings are context-sensitive and may differ in communities where the practice is no longer actively performed.

A total of 12 participants were involved in this study, consisting of six practitioners, three cultural elders, and three mathematics teachers. The sample size was determined based on data saturation rather than numerical representativeness, in line with qualitative research principles (Patton, 2015). Saturation was reached when no new geometric patterns or meanings emerged across two consecutive interviews. Participants were selected using purposive sampling to identify initial informants, followed by snowball sampling to expand the participant pool. To reduce sampling bias, participants were drawn from different social clusters, and cross-verification was conducted across participant types. The saturation indicator was confirmed through redundant coding categories identified among the final three participants.

Data were collected through three primary techniques: participant observation, semi-structured interviews, and documentation. Participant observation was conducted at a moderate level of involvement, focusing on the spatial arrangement process and recorded in the form of detailed field notes and sketch reconstructions. Semi-structured interviews were conducted with all participants (n = 12), each lasting between 30 and 60 minutes, and were audio-recorded and transcribed verbatim. Documentation included photographs taken from standardized angles and visual reconstructions of arrangement patterns. To control for reactivity, repeated observations were conducted to reduce the potential influence of participants' awareness of being observed.

The research instruments consisted of an observation guide and an interview guide. The observation guide, which had been validated by experts, included indicators such as circularity (closed radial arrangement), symmetry (equal distribution across axes), and proportionality (equal spacing ratio). The interview guide contained open-ended questions, such as "What rules guide the arrangement?" and "How do you decide spacing?" Instrument validity was ensured through expert validation involving two experts in ethnomathematics and mathematics education, followed by pilot testing with two participants. Revisions were made prior to the main data collection.

The data collection procedure followed a systematic sequence, beginning with preliminary mapping of the cultural practice, followed by instrument validation, pilot testing, main data collection, transcription, and reflexive documentation. A contingency protocol was implemented such that if new patterns emerged during analysis, additional observation sessions were conducted to ensure completeness of data.

Data were analyzed using the interactive model proposed by Miles, Huberman, and Saldaña (2014), which includes data reduction, data display, and conclusion drawing and verification. The unit of analysis in this study was the arrangement pattern, including both visual structures and verbal explanations provided by participants. The coding scheme was operationalized as follows:

Table 1. Data Code

Data	Code	Category	Concept
Circular fish layout	CIRC	Shape structure	Circle
Equal spacing	PROP	Spatial relation	Proportionality
Balanced sides	SYM	Pattern	Symmetry

The coding process was conducted in three stages: open coding to identify initial patterns, axial coding to group these patterns into categories, and selective coding to connect categories with pedagogical implications. To ensure reliability, an independent second coder reviewed the data, resulting in an agreement rate of 87%. Any discrepancies were resolved through discussion to reach consensus.

The analytical framework of this study followed a three-layer model consisting of cultural practice, geometric structure, and pedagogical transformation. The operational flow of analysis proceeded from raw data to coding, followed by concept mapping, and finally to instructional representation. This framework ensured a systematic linkage between empirical data and educational application.

To ensure validity and trustworthiness, this study adopted the criteria proposed by Lincoln and Guba (1985). Credibility was achieved through data triangulation and member checking, whereby participants verified the interpretations. Dependability was ensured through a detailed audit trail documenting all research procedures. Confirmability was established through an external audit conducted by an expert reviewer. Transferability was supported by providing a rich and detailed description of the research context.

Ethical considerations were strictly observed throughout the study. Written informed consent was obtained from all participants prior to data collection. Participant anonymity was maintained using coded identifiers (P1–P12). All data were securely stored and used solely for research purposes, and cultural sensitivity was maintained during all interactions with participants.

3. Results and Discussion

The results of this study indicate that the cultural practice of *Ikan Keturi Piring* embodies structured geometric principles that emerge through culturally regulated spatial arrangements. Across six observation sessions conducted in both domestic and communal contexts, the arrangement of fish consistently formed a circular configuration centered on a focal point, with inward orientation and relatively uniform spacing.

Figure 1 Presents visual example of the *Ikan Keturi Piring* arrangement observed during the study.

As shown in Figure 1, the arrangement of fish forms a circular pattern with relatively equal spacing between each element. Each fish is positioned at an approximately equal radial distance from the center, suggesting an implicit understanding of circularity and symmetry. The distribution also indicates an intuitive partitioning of space into near-equal angular segments. Visual examination of annotated sketches further confirms that each element is positioned at approximately equal radial distance and angular separation, suggesting an implicit partitioning of space into near-equal sectors.

Participants articulated this principle through culturally embedded expressions such as “harus rata supaya tidak berat sebelah” (P2), “dibagi sama supaya rapi” (P6), and “kalau miring sedikit saja, langsung diperbaiki” (P1). These statements reveal iterative adjustment processes, in which individuals continuously evaluate and reposition elements to maintain spatial equilibrium. Notably, in one observed case, slight asymmetry in spacing was tolerated due to practical constraints, indicating that geometric precision is dynamically negotiated within cultural contexts rather than strictly formalized.

From an analytical perspective, these findings reveal a multi-layered generative mechanism through which geometry emerges from cultural practice. At the first level, cultural norms emphasizing balance and harmony function as cognitive constraints that guide action. At the second level, these constraints produce iterative spatial regulation, where each placement is adjusted relative to others to maintain equilibrium. At the third level, this process results in emergent geometric structures, including circularity, radial symmetry, and implicit angular partitioning approximating 360° divided by the number of elements. Importantly, this mechanism demonstrates that geometric reasoning is not externally imposed but internally constructed through embodied cultural activity. However, an alternative interpretation must also be considered: these patterns may initially appear as aesthetic rather than mathematical. Yet, the consistency and regularity observed across participants suggest that aesthetic judgment operates through structured spatial reasoning, thereby functioning as an implicit mathematical system.

Theoretically, these findings both support and extend the framework of ethnomathematics. Consistent with D'Ambrosio (1985), mathematical ideas are embedded in cultural practices. Similarly, Bishop's (1988) concept of mathematical activity is reflected in the structured arrangement process, particularly in acts of designing and organizing space. However, this study goes beyond prior work by demonstrating that cultural practices do not merely contain mathematical elements but actively generate mathematical structures. In this sense, the study extends the work of Rosa and Orey (2016) by introducing a process-based understanding of ethnomathematics, shifting it from a descriptive orientation toward a generative framework. This repositioning has important theoretical implications, as it frames culture as an epistemological source of mathematical knowledge rather than a contextual supplement.

In comparison with previous studies, this research offers a more analytically robust contribution. While earlier studies such as Sarwoedi et al. (2018) and Zayyadi (2017) successfully identify mathematical elements within cultural artifacts, they do not sufficiently explain the mechanisms through which these elements emerge, nor do they provide pathways for instructional integration. Recent literature has also noted that although ethnomathematics enhances student engagement, its application in classrooms often lacks systematic structure. This study addresses these limitations by explicitly modeling the transformation from cultural practice to geometric reasoning and pedagogical application. Thus, the present study not only supports existing findings but also extends them by providing a mechanism-based and instructional framework.

The emergence of geometric structures in *Ikan Keturi Piring* can be further explained through the interaction of aesthetic, cultural, and functional dimensions. Aesthetic considerations drive the need for visual balance, cultural norms reinforce harmony and order, and functional considerations ensure efficient use of space. These dimensions operate simultaneously to produce stable yet flexible spatial configurations that align with formal geometric principles. This triadic interaction suggests that geometry, in this context, is not an abstract system imposed externally but a situated form of knowledge constructed through lived cultural experience.

The pedagogical implications of these findings are significant and can be operationalized into instructional practice. For example, in a geometry lesson, students can be guided to observe the arrangement of *Ikan Keturi Piring*, count the number of elements, and calculate the central angle using the relationship 360° divided by the number of objects. This can be followed by hands-on activities in which students recreate the arrangement using physical objects, thereby experiencing geometric concepts through embodied learning. Such an approach aligns with culturally responsive pedagogy (Gay, 2018; Ladson-Billings, 2021), which emphasizes the integration of students' cultural backgrounds into the learning process. Importantly, this approach not only contextualizes learning but also supports deeper conceptual understanding by linking abstract ideas to meaningful experiences.

Conceptually, this study proposes a refined framework: Cultural Rules → Cognitive Constraints → Iterative Spatial Regulation → Emergent Geometry → Pedagogical Transformation. This framework advances ethnomathematics by positioning culture as a generator of mathematical knowledge rather than merely a contextual background. Pedagogically, it provides a structured pathway for integrating cultural practices into formal mathematics instruction, thereby bridging the gap between theory and classroom practice.

Despite these contributions, several limitations must be acknowledged. First, the findings are context-specific and derived from a single cultural practice, which may limit their generalizability. Second, the interpretation of geometric structures is influenced by the researcher's analytical perspective, which may introduce bias despite reflexive efforts. Third, the absence of quantitative measurement limits the precision of geometric claims. Future research should therefore explore similar mechanisms across different cultural contexts and examine the effectiveness of the proposed pedagogical framework in classroom implementation.

In synthesis, this study demonstrates that the cultural practice of *Ikan Keturi Piring* embodies emergent geometric principles generated through culturally regulated spatial processes. By revealing the mechanism through which cultural rules produce geometric understanding and by translating this mechanism into pedagogical application, this study contributes to the advancement of mathematics education as a culturally grounded and epistemologically rich field.

4. Conclusion

This study set out to examine how geometric concepts are embedded within and emerge from the cultural practice of *Ikan Keturi Piring*, while also exploring their transformation into meaningful geometry learning. The findings demonstrate that geometric reasoning—manifested through circularity, radial symmetry, proportional spacing, and implicit angular partitioning—emerges as a culturally regulated cognitive process rather than a product of formal abstraction. In this regard, the study not only answers the research questions by identifying embedded geometric structures and explaining their mechanism of emergence, but also synthesizes these insights into a coherent understanding of how culture shapes mathematical cognition.

Theoretically, this study advances ethnomathematics beyond a descriptive paradigm by proposing a generative framework in which cultural rules function as cognitive constraints that drive iterative spatial regulation, ultimately producing emergent geometric structures. These reframing positions culture not merely as a contextual backdrop, but as an epistemological engine of mathematical knowledge production, thereby extending existing perspectives in a conceptually significant way. Practically, the study offers a concrete pedagogical pathway for integrating cultural practices into geometry instruction, such as engaging students in analyzing circular arrangements and calculating central angles (e.g., 360° divided by the number of elements), thus fostering meaningful and embodied mathematical understanding.

This study demonstrates that geometry is not inherently abstract, but emerges through culturally mediated practices that structure human interaction with space. However, the findings remain context-specific, as they are derived from a single cultural setting and rely primarily on qualitative interpretation without quantitative validation of geometric precision. Accordingly, future research should extend this framework across diverse cultural contexts and employ experimental or mixed-method designs to evaluate its effectiveness in classroom implementation.

In conclusion, this study repositions mathematics not as knowledge detached from lived experience, but as a form of reasoning that is generated, shaped, and sustained within culture—thereby challenging the conventional boundary between formal mathematics and everyday life.

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