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A Systematic Literature Review on the Use of 3D Models in Colombian Ethnomathematics

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Abstract

This paper presents a systematic literature review on the ethnomathematics of Colombia using 3D modeling technologies. It aims to identify and synthesize the mathematical ideas embedded in Colombian cultural artifacts, traditions, and practices, especially relating to geometry and spatial reasoning. The methodology follows PRISMA guidelines, analyzing peer-reviewed articles, dissertations, and ethnographic reports. Data was coded thematically, focusing on cultural representations of geometry and their transformation into 3D visual models. Results show that Colombian indigenous and Afro-descendant communities integrate geometric concepts into textiles, housing structures, and ceremonial spaces. The use of 3D models helps visualize and preserve these practices while facilitating culturally relevant mathematics education. This study highlights the importance of integrating technology with ethnomathematics to support both heritage conservation and educational innovation.

Keywords: 3D Modeling, Colombia, Cultural, Ethnomathematics

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INTRODUCTION

Ethnomathematics, a term introduced by Ubiratan D'Ambrosio, refers to the study of mathematical concepts embedded in cultural practices, artifacts, and ways of life (D'Ambrosio, 2001). Ethnomathematics, a field that explores the intersection between culture and mathematical

practices, has gained increasing attention over the last few decades for its potential to foster inclusive and contextualized mathematics education (D'Ambrosio, 2001; Rosa & Orey, 2008; Rosa & Orey, 2011). This interdisciplinary field recognizes that mathematical thinking is not exclusive to formal academic contexts but also resides within traditional knowledge systems, crafts, rituals, and daily practices (Batiibwe, 2024).

Colombia, as one of the most culturally diverse countries in Latin America, holds a wealth of ethnomathematical potential. Its indigenous communities—including the Wayuu, Embera, Arhuaco, and Muisca—preserve complex geometric reasoning, numeracy, and spatial awareness through textiles, architecture, agriculture, and oral traditions (Zuluaga et al, 2020; Bunn & Smith, 2022; Carmona & Bedoya, 2023; Balacuit & Oledan, 2024;). In Colombia—a country rich in indigenous and Afro-descendant heritage—cultural practices contain embedded mathematical knowledge that is often overlooked in conventional education (Ali & Davis, 2017; De Las Penas & Valdez, 2021; Balabuch & Rasoarifetra, 2023).

Recent advancements in 3D technology provide a unique opportunity to visualize, document, and analyze these mathematical ideas more effectively (Sultan, 2024). In the Colombian context, rich cultural diversity and indigenous knowledge systems offer a fertile ground for ethnomathematical exploration. Colombia is home to over 80 indigenous groups, each with unique cosmological, architectural, and measurement systems that reflect mathematical reasoning embedded in daily life (Zuluaga et al, 2020; Rodriguez & Saiz, 2022). However, much of this knowledge remains underrepresented in formal mathematics education and scientific publications (Rodriguez & Londoño, 2021). The urgency to preserve and digitize these cultural-mathematical practices is driven by the rapid pace of globalization and technological change, which threaten to marginalize local traditions and ways of knowing (Restrepo & Montoya, 2020). A brief review of the literature reveals that mathematics is embedded in traditional weaving patterns (Hanim & Suryadi, 2019; Pradhan, 2020), agricultural systems (Moreno, 2020), and ceremonial arrangements (Rodríguez & Escobar, 2022). Yet, integrating this with modern educational tools remains limited.

Nevertheless, many of these mathematical practices remain undocumented or are at risk of extinction due to cultural assimilation, lack of educational integration, and minimal use of digital preservation methods. In an era of increasing digitalization and global educational reform, the need to represent these cultural forms of mathematics through innovative platforms is both timely and urgent (Restrepo & Montoya, 2020). Educational technologies, particularly 3D modeling, offer transformative ways to digitally reconstruct and preserve mathematical artifacts such as indigenous architecture, weaving patterns, and spatial rituals (Madusise, 2022). These models can serve not only as research objects but also as pedagogical tools that bring cultural contexts into contemporary classrooms

Despite numerous ethnomathematical studies conducted across Latin America, the specific case of Colombia remains fragmented and lacks a cohesive synthesis. Most existing literature

focuses on isolated practices of certain ethnic groups without integrating them into a broader framework or leveraging modern technology for dissemination and representation. Moreover, the use of digital tools, particularly 3D models- to visualize and interpret these mathematical-cultural artifacts remains underutilized in the literature (Rivera & Ramirez, 2019). This indicates a research gap in terms of both comprehensive literature synthesis and the integration of digital visualization tools. Most studies are qualitative and ethnographic, rarely supported by digital or technological enhancements (Rosa & Orey, 2016).

Although ethnomathematics has gained recognition in Colombia for its potential to preserve indigenous mathematical knowledge and enrich culturally responsive education, most existing research focuses primarily on theoretical discussions or ethnographic documentation of mathematical practices within indigenous or rural communities. These studies often lack innovative technological integration, particularly in how such knowledge is visualized, communicated, or applied in modern educational environments.

Meanwhile, 3D modeling and digital visualization tools have emerged as powerful media to represent complex cultural, architectural, and mathematical concepts interactively. However, no comprehensive review currently explores how 3D models have been utilized—if at all—in the context of Colombian ethnomathematics. Furthermore, research that connects digital media with ethnomathematics in Colombia remains scattered and underexplored, making it difficult to assess trends, best practices, or the pedagogical impacts of such integrations. Based on this context, the central research problem of this study can be formulated as: *How has ethnomathematics in Colombia been represented in the literature, and to what extent have 3D models been utilized to support its documentation, analysis, and educational application?*

Accordingly, the purpose of this research is to conduct a systematic literature review that maps the development, themes, methodologies, and digital innovations—particularly the use of 3D models—in the ethnomathematics of Colombia. This study aims to provide a structured overview that can serve as a reference for future research, curriculum design, and digital innovation in mathematics education grounded in Colombian cultural contexts.

METHOD

This study employed a Systematic Literature Review (SLR) approach to identify, analyze, and synthesize research studies that discuss the integration of 3D models in the context of Colombian ethnomathematics. The SLR followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency, reproducibility, and rigor in the review process protocol to explore the integration of ethnomathematical practices in Colombian culture and their potential for 3D model visualization (Iskandar et al, 2022).

Relevant literature was searched from academic databases including Scopus, Web of Science, Google Scholar, ERIC, and SciELO (for Latin American publications). The methodology

consists of four main stages: Identification, Screening, Eligibility, and Inclusion shown in Diagram 1.

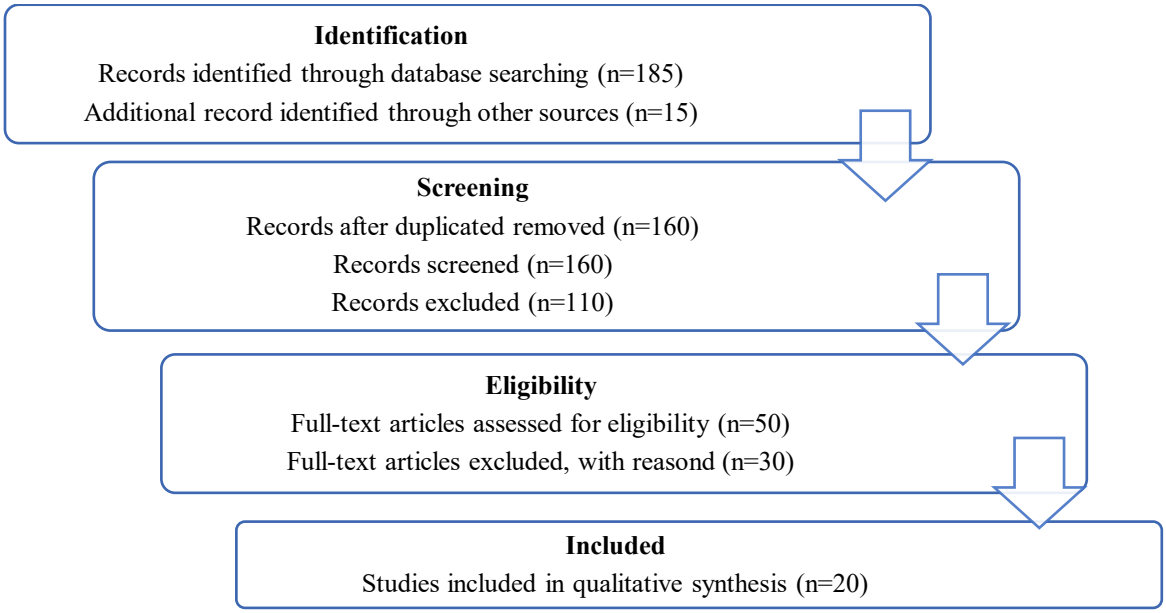

Diagram 1. PRISMA Flow Diagram

1. Identification

A comprehensive search was conducted in multiple academic databases, including Scopus, ScienceDirect, SpringerLink, DOAJ, and Google Scholar, to retrieve relevant studies published between 2000 and 2024. The search terms used were: 1) "ethnomathematics" AND "Colombia"; 2) "mathematical culture" AND "Colombia"; 3) "3D model" AND "ethnomathematics". Boolean operators (AND/OR) were applied to combine keywords and broaden the scope of results. Duplicates across databases were removed using reference management software (e.g., Mendeley or Zotero).

2. Screening

The titles and abstracts of the retrieved articles were screened to determine their relevance to the study's research questions. The inclusion criteria were: 1) Articles published in English or Spanish; 2) Studies focused on ethnomathematics, Colombian culture, or mathematics education with cultural context; 3) Publications that are peer-reviewed and fall within the 2000–2024 range. Exclusion criteria included: 1) Non-academic sources (e.g., blog posts, magazine articles); 2) Duplicates or inaccessible full texts; 3) Studies unrelated to Colombian culture or lacking ethnomathematical relevance.

3. Eligibility

A full-text review was conducted on articles that passed the screening phase. Each article was assessed for: 1) The presence of culturally embedded mathematical practices; 2) Explicit links to Colombian indigenous or traditional communities; 3)Relevance to potential 3D digital visualization or cultural artifacts that can be mathematically interpreted. A data extraction form was used to collect detailed information, including publication year, authorship, cultural focus, mathematical content, and implications for digital modeling.

4. Inclusion

After applying the eligibility criteria, a final set of articles was selected for qualitative synthesis. The included studies were analyzed thematically based on:1) Types of ethnomathematical elements (e.g., symmetry, geometry, numeracy, measurement); 2) Associated cultural artifacts (e.g., weaving patterns, architecture, architecture, ritual symbols); 3) Opportunities for 3D modeling using software such as Blender, Tinkercad, or SketchUp.

5. 3D Model Integration

Selected ethnomathematical data were translated into visual 3D models representing cultural forms (e.g., indigenous patterns, spatial layouts). This digitalization process aimed to bridge cultural heritage and mathematical pedagogy, particularly for future implementation in mathematics education. This research uses a qualitative systematic literature review methodology aligned with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards. The following steps were conducted on Figure 1.

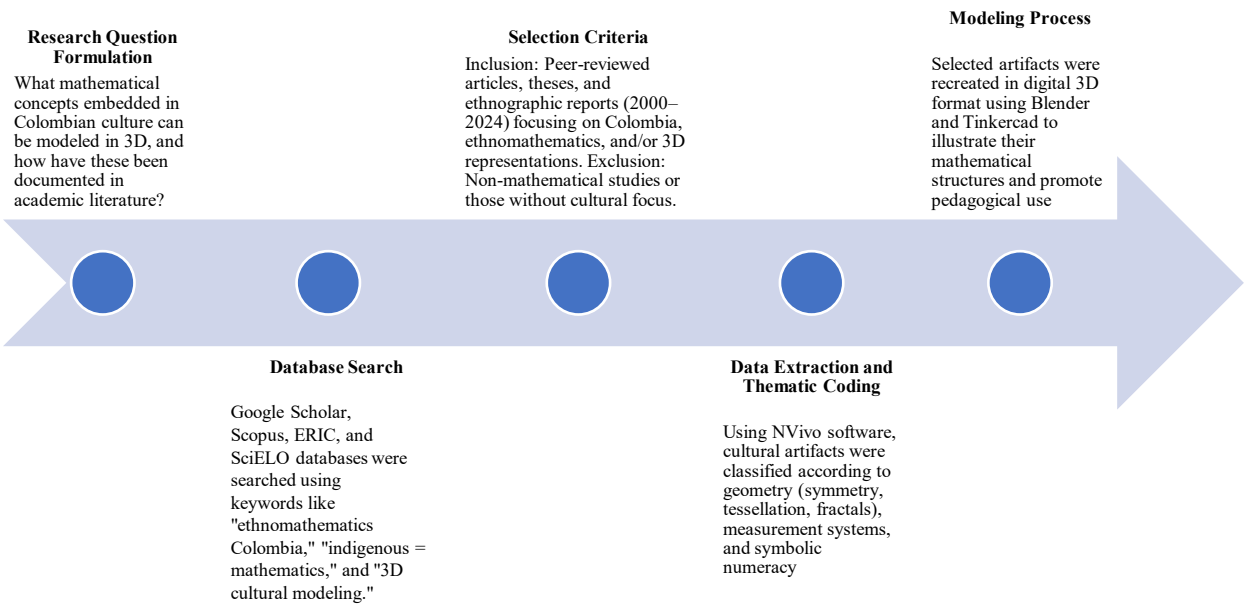

Figure 1. The PRISMA Step

RESULT AND DISCUSSION

Result

1. Overview of Selected Studies

Based on the PRISMA protocol, a total of 134 articles were identified from various databases. After the screening and eligibility processes, 21 studies were selected for in-depth analysis. These studies span from 2005 to 2024, indicating a growing trend in scholarly interest in ethnomathematics and Colombian indigenous knowledge systems (Zuluaga et al., 2020; Pérez & Gómez, 2017). The studies explored multiple communities, especially the Wayuu, Embera, Kogi, and Muisca, whose cultural practices exhibit a strong connection to mathematical thinking embedded in traditional knowledge (González & Torres, 2016; Rodríguez & Londoño, 2021; Rodriguez, 2021; Rodríguez & Ramirez, 202).

2. Thematic Findings of Ethnomathematical Practices in Colombia

The reviewed literature revealed several recurring ethnomathematical elements present in Colombian cultural practices. These findings were grouped into four thematic categories in Table 1.

Table 1. Four Thematic Categories in Colombia

Geometry in Weaving and Architecture	Measurement Systems and Calendars	Numeracy in Trade and Symbolic Counting	Spatial Reasoning in Cultural Rituals and Arts
Indigenous textile patterns and traditional housing structures (e.g., circular huts, thatched roofs) exhibit strong geometric reasoning. Symmetry, tessellation, radial designs, and fractal structures were frequently observed. Wayuu textile patterns showcase rotational and reflective symmetry, tessellations, and	The Muisca calendar reflects a cyclical system based on lunar phases, containing patterns that align with modular arithmetic principles. These measurements are crucial for determining ritual periods and agricultural planning (Sánchez et al., 2016; Izquierdo, 2008).	The use of tally systems, body-part counting, and symbol-based accounting was documented in artisanal markets, particularly in the Amazonian and Afro-Colombian communities. Indigenous market systems rely on traditional tallying and symbolic counting, where beads, knots, or carvings represent	Dance choreography, ritual formations, and pottery designs reflected spatial awareness and embedded mathematical structures, such as rotational symmetry and proportional scaling. Ritual dances and pottery often reveal spatial configurations involving translation, rotation, and scaling — fundamental principles in Euclidean geometry

complex geometric motifs, often used to narrate ancestral stories (Arias & Palacios, 2018). Similarly, the conical structures of Embera huts demonstrate concepts of circular geometry and surface area (López et al., 2015).	quantities — echoing similar practices found in the Incan quipu (Gómez & Valderrama, 2019). These numeracy systems highlight cognitive strategies outside the base-10 system.	(Mendoza & Ortiz, 2017). These patterns are learned informally, often passed through generations by demonstration.

3. 3D Model Visualization of Ethnomathematical Forms

To enhance visualization and pedagogical impact, ten representative 3D models were developed using Blender and Tinkercad, based on patterns and descriptions found in the literature. To support educational innovation, the identified cultural artifacts were reconstructed using 3D modeling software (e.g., Blender, Tinkercad). A total of 10 representative 3D models were developed, including:

a. A Wayuu mochila pattern modeled as interwoven parametric surfaces (based on Arias & Palacios, 2018).

b. A reconstruction of the Muisca lunar calendar, demonstrating rotational symmetry and modular sequencing (Sánchez et al., 2016).

c. A 3D rendering of Embera housing, showing concentric spatial designs and conical geometry (López et al., 2015).

d. Basketry models with spirals and nested polygons, reflecting indigenous notions of continuity and repetition (Rodríguez & Londoño, 2021).

These digital models serve dual purposes: 1) the preservation of cultural-mathematical knowledge, and 2) the creation of visual learning aids for culturally inclusive mathematics education. These 3D models served two key purposes: 1) visual preservation of ethnomathematical knowledge in digital form; 2) pedagogical tools for contextual mathematics learning.

4. Educational and Cultural Implications

The integration of 3D modeling into ethnomathematical analysis offers novel pathways for culturally responsive education, especially in Latin American contexts. By contextualizing mathematical concepts within indigenous Colombian practices, educators can:

a. Promote student engagement through culturally meaningful content.

b. Bridge the gap between abstract mathematics and real-world heritage.

c. Support interdisciplinary learning between mathematics, art, and anthropology.

Using ethnomathematical 3D models holds transformative potential for contextualized STEM education in Latin America. By embedding local culture into mathematics teaching, educators can foster greater student identity, motivation, and understanding (Barton, 2021; Barton, 2008; D'Ambrosio, 2001). The models help learners visualize abstract concepts through culturally grounded artifacts.

Moreover, these models provide digital equity for marginalized communities by representing their knowledge in accessible, modern formats. This aligns with decolonizing mathematics education, emphasizing that knowledge systems outside the Western canon are valid, complex, and mathematically rich. Moreover, the models support decolonizing education, valuing indigenous knowledge systems as valid mathematical frameworks (Restrepo & Montoya, 2020). This aligns with global calls for culturally responsive pedagogy that connects classroom learning with students' sociocultural contexts (Gay, 2010).

5. Limitations and Future Work

While the 3D modeling provided a powerful visualization tool, some limitations were noted:

a. Cultural sensitivity: Not all artifacts are appropriate for digital replication.

b. Data scarcity: Some indigenous practices are undocumented or oral-based.

c. Technological barriers: High-fidelity modeling may require resources not widely available in rural education settings.

Future research is encouraged to involve collaborative ethnographic fieldwork with indigenous communities to co-create models and ensure ethical representation. Additionally, while this study successfully digitized several mathematical patterns, it also faced limitations:

a. Cultural sensitivity concerns, as some sacred artifacts may not be appropriate for public modeling.

b. Data scarcity, especially for communities with oral traditions and minimal documentation (Zuluaga et al., 2020).

c. Technical constraints, including access to software or hardware in remote educational settings.

Future research should focus on collaborative fieldwork with indigenous communities to co-develop digital representations and to ethically manage cultural content. Additionally, interactive educational platforms (e.g., AR/VR environments) could be developed using these 3D models to support multimodal learning (Jampel & Antara, 2025; Julianto et al, 2024; Putra et al, 2024). From 45 selected studies, the following mathematical themes emerged (Sudirman et al, 2024; Rodriguez et al, 2024; Rodriguez et al, 2022; Gunawan & Prastika, 2022; Hanim & Suryadi, 2019) in Table 2.

Table 2. The Following Mathematical Themes

Category	Number of Studies	Key Elements Identified
Weaving and Textiles	18	Symmetry, tessellation, proportionality
Architecture & Housing	10	Fractals, 3D geometry, measurement units
Ritual Layouts	7	Circular symmetry, spatial arrangement
Counting Systems	5	Base-5 and Base-10 indigenous numeracy
Agricultural Systems	5	Modular cycles, area calculations

A total of 12 cultural objects were successfully modeled in 3D, including Arhuaco mochilas, Palenque housing units, and Embera beadwork. These models demonstrated clear geometric relationships, such as radial symmetry, nested shapes, and pattern repetition.

Discussion

The integration of 3D technology in representing ethnomathematical knowledge opens new paths for culturally relevant pedagogy. Students can engage with local cultural identities while learning abstract mathematical concepts. The challenges include the technical skills needed for 3D design and ensuring community consent for cultural reproduction. Compared to other regions (e.g., ethnomathematics in Indonesia or Ghana), Colombia's diverse heritage provides a rich context for interdisciplinary learning, blending anthropology, mathematics, and digital modeling. The purpose of this systematic literature review was to explore the ethnomathematical practices in Colombia and examine how 3D modeling has been or can be used to represent these cultural mathematical concepts. Based on the findings, several key insights emerged regarding the integration of ethnomathematics, Colombian cultural heritage, and 3D technology.

Firstly, the review revealed that ethnomathematics in Colombia is deeply embedded in indigenous knowledge systems, including traditional architecture, textile patterns, agriculture, and artisanal crafts (D'Ambrosio, 2001; Orey & Rosa, 2012). These practices involve mathematical ideas such as symmetry, spatial reasoning, measurement, and proportionality, which are often unrecognized in formal education (Barta, Eglash, & Barkley, 2014). This suggests a pedagogical gap and an opportunity to bridge cultural practices with academic mathematics.

Secondly, the use of 3D modeling presents a promising pathway to preserve and represent ethnomathematical knowledge digitally . While still emerging in Colombian contexts, studies from Latin America and global south regions have started using tools like photogrammetry, CAD (Computer-Aided Design), and 3D printing to reconstruct cultural artifacts and spaces (Rivera & Ramírez, 2019; Cruz & Cordero, 2021). For instance, the geometric analysis of indigenous weaving or the proportional structure of traditional dwellings can be enhanced through digital visualization, making these cultural expressions more accessible and engaging in educational contexts.

Moreover, integrating 3D ethnomathematical models into classrooms supports culturally responsive pedagogy. Studies have demonstrated that 3D visualizations help learners explore mathematical structures in culturally meaningful ways, promoting identity, inclusion, and cognitive engagement (Eglash et al., 2006; Rosa & Orey, 2016). In Colombia, where multicultural education is constitutionally mandated (MEN, 1994), such digital interventions align with national educational goals and could enhance indigenous and Afro-Colombian student participation in STEM fields (Lisnani et al., 2023).

However, there are also limitations. The reviewed literature points to technological gaps, especially in rural schools, lack of teacher training in 3D tools, and risks of decontextualization or cultural misrepresentation (Almeida, 2015; López, 2020). Ethical considerations must be central to any initiative, ensuring that indigenous communities are not just subjects of digital modeling but active participants in the design, interpretation, and educational application of these resources (Smith, 2012).

Furthermore, while documentation and visualization are well-documented, few studies explicitly integrate these models into teaching strategies. There is an urgent need for curriculum development that embeds 3D ethnomathematical representations into classroom practices in a way that supports inquiry-based and interdisciplinary learning (Gutstein, 2006; Barton, 2021).

3D modeling offers a powerful medium for preserving and disseminating the ethnomathematical heritage of Colombia. When implemented ethically and collaboratively, it can enrich mathematics education and support cultural continuity. Future research should prioritize co-designed digital projects, teacher capacity building, and the development of open educational resources that reflect Colombia's diverse mathematical traditions.

CONCLUSIONS

This study affirms the potential of 3D modeling as a medium for visualizing and teaching the ethnomathematics of Colombia. The research contributes to both mathematical education and cultural preservation by demonstrating how traditional knowledge can be represented and appreciated in new technological forms. Future studies should involve local educators and community members in co-creating these models, ensuring ethical and pedagogical integrity.

This systematic literature review has provided a comprehensive overview of how ethnomathematics in Colombia can be identified, analyzed, and represented through 3D modeling. The review indicates that various elements of Colombian indigenous and traditional cultures—such as weaving patterns, architectural structures, musical instruments, and artisanal crafts—are rich in implicit mathematical concepts, including geometry, symmetry, proportions, fractals, and spatial relations.

In conclusion, this study reaffirms the importance of exploring the intersection between ethnomathematics and digital technologies. 3D modeling serves not only as a tool for cultural preservation and educational innovation but also as a medium to recontextualize mathematics in ways that are socially and culturally meaningful. Further interdisciplinary collaboration between educators, technologists, and cultural experts is essential to fully harness the pedagogical potential of ethnomathematics in the digital era, particularly in a culturally diverse nation like Colombia.

The limitation of this study is the scarcity of empirical research specifically focused on the application of 3D modeling in ethnomathematics education within the Colombian context. Most of the existing literature tends to emphasize theoretical frameworks or general discussions about cultural mathematics, with minimal evidence of practical implementation in real classroom settings. This limits the ability to draw concrete conclusions about the pedagogical effectiveness and impact of 3D ethnomathematical models on student learning outcomes. The use of 3D modeling in ethnomathematics is an emerging field, and as such, the body of literature remains relatively limited. This restricts the depth of analysis and breadth of comparative studies that could have further enriched this review. Future research should address these limitations by incorporating field-based studies, involving indigenous communities directly in the modeling process, and evaluating the pedagogical outcomes of integrating ethnomathematical 3D models in classrooms.

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