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A Metasynthesis of the Evolution of Mathematics Learning Spaces in Cultural Enclaves: A Juxtaposed Progression Lattice (JPL) Model

Jay Fie P. Luzano

Bukidnon State University, Malaybalay City, Bukidnon, Philippines,  0000-0001-5305-2419
Corresponding author: Jay Fie P. Luzano (jayfieluzano@bksu.edu.ph)

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Abstract

This study executed a metasynthetic analysis to elucidate the evolving configurations and emergent trajectories of mathematics learning spaces situated within cultural enclaves. Utilizing Cultural-Historical Activity Theory (CHAT) and Third Space Theory as guiding frameworks, the study identified and synthesized patterns across diverse sociocultural contexts. Thematic synthesis reveals four major themes: (1) cultural grounding of mathematical knowledge, (2) spatial and pedagogical fluidity, (3) tensions and transformations in curriculum, and (4) reimagining the future of mathematics learning. Findings indicate that mathematics learning in cultural enclaves is dynamic, adaptive, and deeply intertwined with local knowledge systems and community practices. The study introduces the Juxtaposed Progression Lattice (JPL) Model, conceptualizing the future of mathematics learning as a cyclical yet progressive reconfiguration of space, knowledge, and pedagogy. The results offer key implications for culturally responsive curriculum development, teacher training, educational policy reform, and participatory governance. This metasynthesis contributes to decolonizing mathematics education and affirms the need to reframe learning spaces as culturally-situated and future-oriented.

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Introduction

In recent decades, the discourse on mathematics education has increasingly interrogated the universality and neutrality of mathematical knowledge, especially in the context of culturally diverse learning environments. While mathematics is often perceived as a culturally agnostic discipline, an emerging body of scholarship challenges this view by foregrounding how mathematical concepts are practiced, understood, and transmitted differently across cultural contexts (Manolino, 2024). Cultural enclaves are communities characterized by strong adherence to indigenous, ethnic, or localized knowledge systems which provide a compelling backdrop to explore how mathematics learning unfolds outside the dominant educational paradigms (Payadnya, Putri, Suwija, Saelee, & Jayantika, 2024). In these spaces, the formal, school-based mathematics curriculum often exists in tension with rich, community-embedded mathematical practices that remain largely invisible in mainstream instruction.

Ethnomathematics has emerged as a critical framework for validating and recontextualizing this diverse mathematical knowledge (Umbara, Prabawanto, & Jatisunda, 2023). Building on the work of D'Ambrosio (2013), ethnomathematics affirms that mathematics is culturally constructed, shaped by the sociohistorical realities of communities. However, while many qualitative studies document these culturally grounded mathematical practices, there remains a need to synthesize this growing body of literature to uncover overarching patterns, contradictions, and possibilities. Particularly pressing is the question of how these practices inform the future of mathematics learning and how pedagogical spaces in cultural enclaves are evolving and how these transformations can guide more inclusive and responsive educational policies and practices (Greer, Mukhopadhyay, Powell, & Nelson-Barber, 2009).

In light of rapid globalization, standardization of curricula, and technological integration, the future trajectory of mathematics learning spaces demands critical reflection (Ivars, Fernández, & Llinares, 2020). Traditional classroom setups and externally imposed curricula are increasingly inadequate in addressing the complex needs of learners situated in culturally rich yet structurally marginalized environments (Anyichie, Butler, Perry, & Nashon, 2023). As learning spaces become more fluid, moving across homes, fields, and digital platforms, there is an urgent imperative to reconceptualize mathematics education as a dynamic interaction between culture, space, and pedagogy (Alakoski, Laine, & Hannula, 2024). This reimagination is not merely theoretical as it carries practical implications for how mathematics can serve as a tool for empowerment, cultural continuity, and innovation in cultural enclaves.

To address this gap, this study employs metasynthesis as a methodological approach to systematically analyze and integrate findings from existing qualitative research on mathematics learning in cultural enclaves. Metasynthesis allows for the construction of new interpretations and models from multiple studies, moving beyond the sum of individual findings toward a richer, more cohesive understanding of the phenomenon. Guided by Cultural-Historical Activity Theory (CHAT) and Third Space Theory, this study aims to identify patterns in the ways learning spaces are conceptualized, experienced, and transformed across diverse sociocultural settings. It further seeks to trace how these evolving spaces reflect and respond to local epistemologies, institutional constraints, and future educational aspirations.

This metasynthesis contributes to the broader goal of decolonizing mathematics education by positioning cultural knowledge systems at the center of pedagogical innovation. This study uncovers the ways in which mathematics learning spaces are being reimagined in cultural enclaves. This would also offer both a critique of prevailing educational models and a vision for more inclusive futures and challenge educators, researchers, and policymakers to recognize that mathematics is not merely a universal language, but a living practice shaped by culture, place, and purpose. Finally, this lays the groundwork for culturally-responsive and future-ready mathematics education that empowers communities and affirms their epistemic sovereignty.

Objectives

This study synthesized findings from existing literature on the future trajectory of mathematics learning spaces, with particular attention to their development and impact within cultural enclaves. This sought to derive new insights from a range of qualitative studies, examining the collective outcomes of previous research to generate broader implications for educational practice and policy. Specifically, the research focused on studies that:

1. Identify recurring themes and patterns in qualitative studies related to mathematics learning in culturally distinct environments;
2. Investigate the intersection of mathematics learning and cultural influences, particularly in unique cultural enclaves;
3. Examine the physical, social, cultural, pedagogical, and technological dimensions of mathematics learning environments, with a special emphasis on how these spaces may evolve over time;
4. Explore the relationship between educational outcomes and culturally enriched learning spaces in the context of mathematics instruction;
5. Document the trajectory of mathematics education spaces through theoretical, empirical, and design-based studies; and
6. Conceptualize possible future trajectories of mathematics learning spaces in cultural enclaves based on synthesized findings.

Theoretical Framework

This metasynthesis is anchored on two interrelated theoretical foundations: Cultural-Historical Activity Theory (CHAT) and Third Space Theory. These frameworks are instrumental in interpreting how mathematics learning spaces in cultural enclaves evolve, adapt, and project into the future amid intersecting cultural, pedagogical, and sociopolitical forces.

Rooted in the foundational theories of Vygotsky (1978) and further advanced by Engeström (1987), Cultural-Historical Activity Theory (CHAT) offers a robust framework for understanding learning as a culturally mediated activity embedded within complex, dynamic systems. In the context of this study, CHAT frames mathematics learning spaces as interconnected activity systems, where various components—such as tools, community, rules, and division of labor—interact to shape and influence learning outcomes. Specifically, tools like indigenous numeracy practices and modern mathematical curricula, the community consisting of elders, teachers, and peers,

rules encompassing cultural norms and educational policies, and the division of labor, including roles of knowledge brokers and students, all work together to mediate and guide learning processes. CHAT facilitates a nuanced analysis of several key aspects. First, it examines how traditional and formal educational tools coexist and interact to influence and mediate the learning experience. Second, it highlights the roles of social actors, including teachers, elders, and students, in either maintaining or transforming the learning space. Finally, CHAT allows for the identification of contradictions within or between the systems involved, which often act as catalysts for change and indicate potential future directions for the educational process. Through the application of CHAT, this metasynthesis interprets the transformation of mathematics education not solely as the transmission of content, but as a culturally embedded, collaborative process of meaning-making. This perspective shifts the focus from a linear transfer of knowledge to a dynamic, context-dependent interaction where cultural and social elements play a pivotal role in shaping educational experiences.

Third Space Theory, initially proposed by Bhabha (1994) and later adapted to education by Moje et al (2004), offers a conceptual framework where formal academic knowledge and students lived cultural experiences converge, leading to the creation of hybrid forms of learning and identity. In the context of cultural enclaves, mathematics classrooms serve as potential "third spaces," where indigenous epistemologies and Western academic paradigms intersect, fostering a unique educational environment. This theory provides a lens through which to understand several critical aspects of the learning process. It helps interpret how learners navigate and negotiate between traditional mathematical practices and formal educational structures. Additionally, Third Space Theory illuminates the emergence of pedagogical models that are neither entirely indigenous nor purely conventional but are hybrid and continually evolving. Finally, it sheds light on the reconfiguration of space—both physical and symbolic—as learners and educators collaboratively shape a future-oriented, culturally grounded approach to mathematics education.

Cultural-Historical Activity Theory (CHAT) and Third Space Theory collectively offer a comprehensive theoretical underpinning for this metasynthesis. CHAT highlights the systemic interactions and mediated activities within learning environments, while Third Space Theory concentrates on issues of identity, hybridity, and negotiation. The integration of these two theoretical perspectives provides a deeper understanding of several key elements. First, it allows for an analysis of the structural and cultural forces that influence the shaping of mathematics learning spaces. Second, it sheds light on the tensions and negotiations involved in balancing the preservation of cultural identity with the incorporation of innovative pedagogical practices. Finally, this theoretical synergy offers insights into the potential future trajectories of these learning spaces, particularly within culturally distinct educational contexts.

Method

This study adopted a metasynthesis research design, drawing on the qualitative integration framework articulated by Sandelowski and Barroso (2007), which emphasizes the systematic aggregation and interpretive synthesis of findings from multiple qualitative investigations. Positioned within the paradigm of interpretivist inquiry, this metasynthesis aims to explore and theorize the evolving trajectories of mathematics learning spaces embedded in

cultural enclaves. This study endeavors to generate nuanced conceptual understandings of how cultural identities, pedagogical practices, and spatial dynamics intricately interact to shape mathematics education in localized and culturally bounded contexts. Sandelowski and Barroso (2007) outlined a rigorous and systematic process for conducting metasynthesis of qualitative research, particularly focused on integrating findings to develop new conceptual or theoretical understandings. Their stages are commonly presented in seven (7) key steps, as follows:

Formulating the Research Purpose and Question

This stage involved the formulation of a clear and conceptually grounded research purpose and question, which served as the anchor for all subsequent methodological steps. Drawing upon the interpretive tradition in qualitative research and the metasynthesis model of Sandelowski and Barroso (2007), this study articulated a research aim centered on theorizing the evolution and future trajectories of mathematics learning spaces within cultural enclaves. The primary purpose of this metasynthesis was to generate a higher-order conceptual understanding of how mathematics learning environments in cultural enclaves have been constructed, experienced, and envisioned in diverse qualitative studies.

To achieve this purpose, the study posed the following central research question:

How do qualitative studies conceptualize the evolution and future trajectories of mathematics learning spaces within cultural enclaves?

This central question was supported by the following sub-questions:

1. *What cultural, spatial, and pedagogical themes emerge across studies that describe mathematics learning in culturally embedded contexts?*
2. *How do various qualitative studies interpret the interaction between culture and mathematics pedagogy in designing or implementing learning spaces?*
3. *What future-oriented constructs can be inferred regarding culturally responsive and sustainable mathematics learning environments?*

This stage was also guided by a conceptual understanding of “learning spaces” not merely as physical environments but as culturally-mediated, socially-negotiated, and symbolically-constructed educational spaces. The study foregrounded cultural enclaves as distinct socio-educational ecosystems where indigenous knowledge systems, community values, and mathematics learning converge. This framing ensured that the synthesis was not a mere aggregation of results, but a re-interpretive process that sought to understand how various studies conceptualize mathematics learning through the lens of culture, space, and transformation.

Conducting a Systematic Literature Search

A comprehensive literature search was conducted across major academic databases (Web of Science, Scopus,

ERIC, Google Scholar), using Boolean logic and strategic keyword combinations such as:

1. "Mathematics education" AND "cultural enclave"
2. "Indigenous mathematics learning" OR "ethnomathematics"
3. "learning spaces" AND "cultural context" AND "qualitative"
4. "future of education" AND "mathematics" AND "cultural diversity"

Manual searches of reference lists were also conducted to identify additional studies. The search aimed to capture studies published from 2000 to 2025, covering both historical and contemporary perspectives on mathematics learning in culturally bounded settings.

Appraising and Selecting Studies

Study selection followed the PRISMA framework, progressing through identification, screening, eligibility, and inclusion. To ensure quality and relevance, the CASP checklist for qualitative research was used to appraise studies in terms of methodological rigor and conceptual clarity.

Inclusion Criteria

To ensure rigor and relevance, the selection of studies adhered to the following inclusion criteria:

1. *Type of Study.* Qualitative studies with clearly delineated qualitative findings.
2. *Topic Relevance.* Focus on mathematics education within cultural enclaves, indigenous communities, or socio-culturally unique learning spaces.
3. *Time Frame.* Studies published between 2000 and 2025 to capture both historical and contemporary developments.
4. *Peer Review.* Published in peer-reviewed journals, or reputable academic repositories.
5. *Language.* Studies published in English or Filipino (with reliable translation available).

Exclusion Criteria

1. Studies that do not focus on mathematics education or do not address cultural enclaves or the evolution of learning spaces.
2. Publications outside the scope of mathematics learning (e.g., unrelated fields such as general education without a focus on mathematics).
3. Studies that focus solely on specific grade levels or educational stages without considering broader applications or future trajectories.

Classifying the Studies

As part of the analytical rigor and transparency essential in qualitative metasynthesis, the selected studies were classified thematically and methodologically to serve as a foundational step in guiding the interpretive synthesis. This classification process enabled the researcher to identify points of convergence, divergence, and conceptual

richness across the body of qualitative literature reviewed.

Author and Year

Each study was first cataloged by the name(s) of the author(s) and the year of publication. This information provided temporal anchoring and allowed for the analysis of shifts and continuities in research trends over time. It also facilitated the identification of seminal or influential works and the mapping of the historical development of discourse surrounding mathematics learning in cultural enclaves.

Cultural and Educational Setting

Next, the studies were categorized based on their cultural and educational contexts. This involved identifying the specific cultural enclave, indigenous community, or socio-educational environment in which the research was conducted. Contextualizing each study in its cultural setting was critical, as it allowed for the appreciation of how local traditions, community values, and indigenous knowledge systems shaped mathematics education practices. Attention to setting also enabled the synthesis to capture the geographical and sociocultural diversity of the included studies, contributing to a globally representative perspective.

Research Design and Theoretical Framework

Each study was further analyzed in terms of its qualitative research design—whether it employed ethnography, grounded theory, case study, phenomenology, or narrative inquiry—and the theoretical lens through which data were interpreted. Studies are categorized based on their epistemological and methodological foundations. The researcher was able to assess the alignment of interpretive strategies with the nature of the findings. The identification of theoretical frameworks, such as culturally sustaining pedagogy, funds of knowledge, or critical theory, helped establish how scholars conceptualized the intersection of culture and mathematics learning.

Emergent Themes and Interpretive Findings

Lastly, the studies were mapped according to the central themes and interpretive insights they generated. This involved extracting the core conceptual contributions of each study—whether these involved culturally contextualized teaching practices, spatial dynamics of learning environments, or the role of identity and language in mathematics instruction. The classification of findings supported the development of thematic clusters and cross-study translations that formed the basis of the metasynthesis. Attention was given not only to what themes emerged but also to how they were constructed and situated within each study's cultural and methodological context.

Extracting and Synthesizing Findings

The extraction of qualitative data focused on themes, trends, and conceptual constructs relevant to the evolution

of mathematics learning spaces. An inductive coding approach was used to identify recurring patterns, supported by manual coding techniques to cluster data and ensure analytical transparency.

Findings were synthesized through iterative analysis, enabling the translation of concepts across studies and the emergence of integrative themes that reflect shared and divergent insights. These included cultural epistemologies, pedagogical adaptations, spatial-symbolic representations, and community-centered learning practices.

Synthesizing the Translations (Metasynthesis Proper)

Following Sandelowski and Barroso's emphasis on interpretive integration, the study synthesized the translated findings into higher-order conceptual insights. This involved reinterpreting findings through reciprocal translation, allowing the distillation of overarching constructs that explain the dynamic, culturally-rooted transformation of mathematics learning spaces.

Presenting the Final Synthesis

The final metasynthesis presents a conceptual framework that encapsulates the evolution of mathematics learning spaces in cultural enclaves. The results contribute to both theoretical development and practical implications in designing culturally responsive, future-ready mathematics education models. The synthesis is presented through thematic summaries and visual frameworks to enhance accessibility and application.

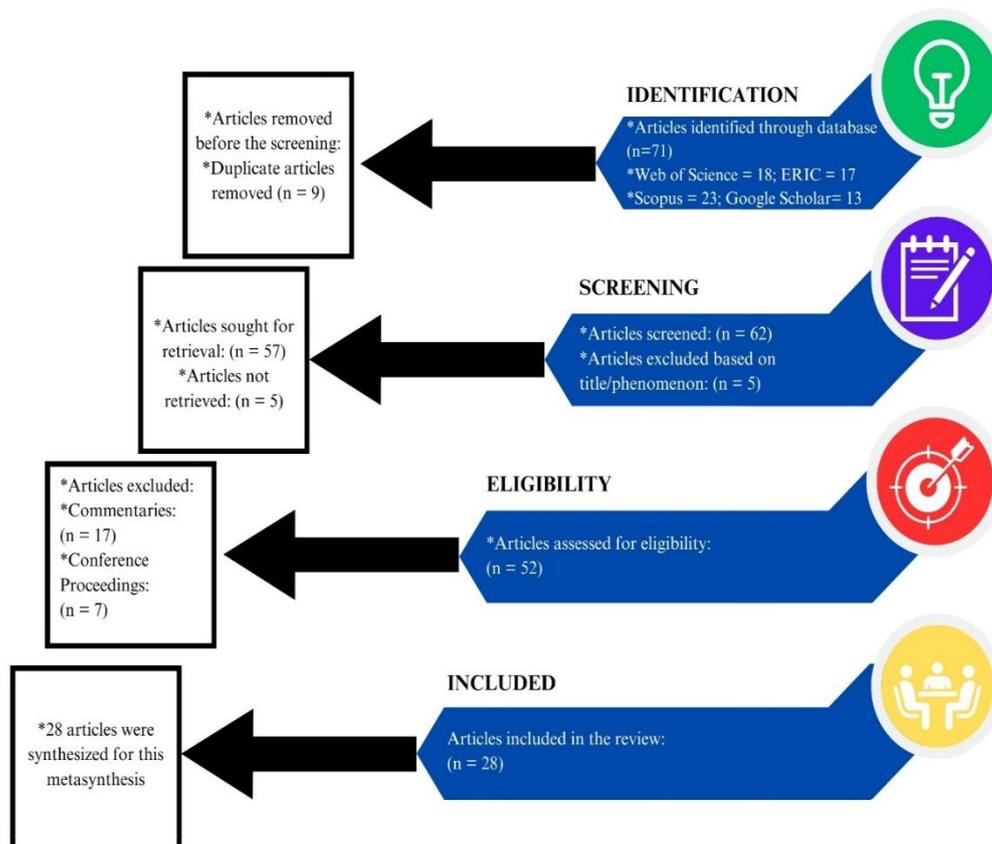


Figure 1. PRISMA Framework of Searching, Selecting, and Abstracting Articles for the Metasynthesis

Results

This metasynthesis yielded a rich tapestry of themes that describe the current state and future trajectories of mathematics learning spaces within cultural enclaves. Through iterative coding and thematic synthesis, four major themes emerged, each supported by a set of subthemes that highlight both convergence and divergence across cultural contexts.

Cultural Grounding of Mathematical Knowledge

Many studies emphasized the centrality of indigenous knowledge systems in shaping the mathematical understandings of learners. Rather than being isolated from cultural practices, mathematics was found to be deeply intertwined with livelihood activities, rituals, architecture, agriculture, and oral traditions. In many indigenous communities, mathematics is not an abstract body of knowledge but a living practice embedded in cultural rhythms, local technologies, and collective memory (Garcia-Olp, Nelson, & Saiz, 2022). A growing body of qualitative research asserts that mathematics, as it is practiced in cultural enclaves, reflects nuanced ways of knowing that differ from, but are no less rigorous than, formal school mathematics. These studies challenge the notion that mathematics is culture-free and universal, revealing instead its contextual, functional, and expressive dimensions.

Indigenous mathematical knowledge as evident in rituals, crafts, land measurement, and social organization—offers a rich tapestry of cognitive strategies and symbolic systems (Berkes & Berkes, 2009). This grounding in local lifeways transforms mathematics from a school subject into a relational activity that cultivates identity, continuity, and survival. When such knowledge is recognized and integrated into formal learning, the result is not merely a curriculum enhancement but an epistemological shift—one that acknowledges multiple mathematical worlds coexisting in a pluralistic society. This theme presents a critical insight that mathematics is not only what is taught in classrooms, but what is practiced and lived in communities. Recognizing indigenous mathematical epistemologies as valid and instructive challenges the cultural monocropping of school curricula. Integrating ethnomathematics, cultural artifacts, and local knowledge bearers into learning processes can foster both academic achievement and cultural pride—building bridges rather than binaries between tradition and modernity.

Ethnomathematics as a Bridge between Traditional and Formal Learning

Ethnomathematics has emerged as a powerful lens through which the mathematical practices of non-dominant cultures are made visible and legitimate (Chahine, 2020). Far from being folkloric, these practices embody sophisticated reasoning strategies, estimation techniques, and spatial reasoning skills, often cultivated through intergenerational apprenticeship. Studies showed that when learners see their home practices echoed in school mathematics, may it be through rice planting cycles, fishing patterns, or weaving symmetry, then they will experience a deeper sense of ownership and competence (Anderson & Gold, 2006).

This bridge, however, is not merely symbolic. Ethnomathematics provides concrete pedagogical pathways for making formal content more comprehensible. For instance, teaching fractions using customary land division

practices or probability through seasonal farming decisions allows students to connect abstract symbols with lived realities. The result is a dual fluency, learners gain mastery in school mathematics while preserving and valuing their cultural heritage.

Recognition of Cultural Artifacts as Valid Mathematical Expressions

Cultural artifacts—like textile patterns, native counting systems, and house-building proportions—serve as repositories of mathematical knowledge (Braswell, 2021). Their recognition as valid forms of mathematical expression repositions the cultural communities not as deficient in mathematical exposure, but as innovators in their own right. This shift in perspective is not merely academic—it has pedagogical and policy implications.

Many studies argue that when these artifacts are incorporated into curriculum materials or classroom dialogue, students engage more meaningfully with mathematical concepts (Swidan & Faggiano, 2021). Moreover, it disrupts the colonial hierarchy of knowledge, where Western constructs dominate while local practices are seen as peripheral. Recognizing these artifacts as intellectual contributions reorients education toward inclusivity and epistemic justice.

The Role of Elders and Community Knowledge Holders as Informal Educators

Elders and local experts—herbalists, weavers, navigators—play a foundational role in transmitting mathematical knowledge through storytelling, modeling, and apprenticeship (Pugacheva et al., 2020). They serve as *"living textbooks"* whose insights are contextual, experiential, and deeply intuitive. Rather than relying on decontextualized content, learners in these communities often learn through observation, participation, and embodied cognition.

Yet, their role remains underutilized in formal education settings. By not inviting these knowledge holders into the pedagogical process, schools miss out on enriching the curriculum with locally-grounded insights. Including elders not only strengthens cultural continuity but also provides learners with role models who embody wisdom, resilience, and localized expertise.

Spatial and Pedagogical Fluidity

The physical and symbolic spaces where mathematics learning takes place were found to be fluid and adaptive. In cultural enclaves, learning extends beyond formal classrooms into homes, fields, and community centers. Mathematics learning in cultural communities often defies the spatial and temporal boundaries of the classroom. Research revealed that the locus of learning shifts fluidly between homes, marketplaces, farmlands, and rituals, demonstrating that cognition does not reside solely within four classroom walls (Civil, 2002). This distributed learning approach privileges context-sensitive engagement, with learners drawing on immediate environments to make sense of mathematical problems.

Educators working in these spaces often display remarkable pedagogical agility. They recognize that effective

teaching requires more than transmitting content—it involves interpreting cultural signals, adjusting to local rhythms, and using multilayered modalities (Fidan, 2022). Spatial fluidity is thus mirrored by pedagogical fluidity which posits that learning unfolds wherever meaning can be made, and teachers become facilitators of that meaning-making across diverse settings. This theme underscores the adaptive intelligence of educators and learners in creating meaningful learning environments beyond institutional norms. By recognizing learning as context-bound, multimodal, and relational, it becomes possible to reframe pedagogy as a co-constructed and culturally-anchored process. Such flexibility does not dilute academic rigor but rather expands its possibilities by meeting learners where they are.

Hybrid Learning Spaces

In many communities, the classroom is just one of the many nodes in the learning ecosystem. Teachers bring in examples from market prices, rainfall measurements, or traditional games to illustrate concepts like arithmetic, geometry, or probability (Reid, 2016). These hybrid spaces of learning collapse the dichotomy between "*school mathematics*" and "*real-life mathematics*", allowing learners to understand that both operate by logic, albeit of different kinds. Studies revealed that when students are encouraged to bring their home experiences into the classroom, their confidence and participation improve (Lee & Lee, 2019). Solving mathematics problems rooted in their own cultural narratives helps them not only grasp the concepts but also validate their lived experiences. Learning becomes reciprocal when students contribute knowledge as much as they receive it.

Pedagogical Flexibility among Teachers

Teachers in culturally diverse contexts often improvise, translate, and reframe concepts to align with the learners' cultural schemata (Szelei, Tinoca, & Pinho, 2019). This flexibility is not a sign of pedagogical looseness but of cultural responsiveness. Storytelling, metaphor, gesture, and games often replace traditional lecturing in these settings, enabling deep conceptual understanding. Rather than adhering to a rigid lesson plan, these educators engage in dialogic teaching, negotiating meanings with students through culturally attuned examples. Studies emphasized that such flexibility enhances not only comprehension but also classroom relationships, as students feel seen, heard, and respected. In this way, pedagogy becomes both relational and reflective (Gravett, Taylor, & Fairchild, 2021).

Use of Local Language and Multisensory Tools

Language and cognition are intertwined, and nowhere is this clearer than in mathematics learning. In multilingual communities, using local languages to explain concepts allows for clearer processing and reduces cognitive load (Moschkovich, 2006). Moreover, multisensory teaching tools—using realia, drawings, songs, or touch-based materials—enhance engagement and retention. Researchers observed that when learners could manipulate objects or explain in their mother tongue, they performed better on assessments and exhibited more complex reasoning. These strategies acknowledge the embodied and linguistic nature of learning, resisting the reduction of mathematics to symbolic manipulation alone.

Tensions and Transformations in Curriculum

Several studies revealed tensions between the standardized, centralized mathematics curriculum and the lived experiences of learners in cultural enclaves. These tensions often manifest in curricular alienation, reduced engagement, and perceived irrelevance of content. Despite the richness of indigenous mathematical knowledge and the dynamic environments in which learning occurs, many studies highlight deep-seated tensions between standardized curricula and the lived realities of learners (Hughes, 2020). The prescriptive nature of national mathematics curricula often leaves little room for contextualization, inadvertently marginalizing students whose cultural knowledge does not align with textbook content. This dissonance can result in a sense of curricular alienation, where learners struggle not because of a lack of ability, but because of a mismatch in epistemologies. Teachers, caught between institutional mandates and the needs of their communities, often navigate these tensions with limited support. They are asked to deliver content aligned with national assessments, even when it contradicts the cultural logic of their learners' environments. However, amidst these challenges, there are signs of hope—grassroots innovations, teacher-led adaptations, and community-involved reforms are emerging as transformative responses (Achinstein, 2002). These movements suggest a growing recognition that curriculum, far from being static, can evolve to reflect the diverse cognitive landscapes of its learners.

This theme illuminates the systemic frictions that arise when a one-size-fits-all curriculum is imposed on culturally diverse learners. Yet it also reveals a quiet revolution that teachers, learners, and communities are actively reimagining the curriculum to better address learners' needs. These transformations suggest that curricular relevance and cultural fidelity are not mutually exclusive, but mutually enriching. A responsive curriculum does not merely accommodate difference but it thrives on it.

Learners' Disengagement due to Lack of Cultural Resonance in Textbook Materials

Textbooks that assume a universal learner identity—often urban, monolingual, and Western-oriented—can alienate students from rural or indigenous contexts (Setyono & Widodo, 2019). When the examples, language, and scenarios in mathematics problems are disconnected from their daily lives, students may fail to see the relevance of what they are learning. This leads to disinterest, lower participation, and in some cases, internalized inferiority.

Several studies documented how learners re-engaged when the curriculum was modified to include locally meaningful contexts—like measuring fields instead of abstract shapes, or using indigenous counting methods (Harker, 2024). These adaptations not only improved academic performance but also validated students' cultural identities, creating a more inclusive and affirming learning experience.

Teachers' Challenges in Contextualizing Abstract Concepts

Teachers, especially those trained in centralized institutions, often struggle to bridge formal mathematical content with the local realities of their students. This difficulty is compounded by a lack of culturally-relevant teaching resources and insufficient training in contextualized pedagogy (Tai & Wei, 2020). As a result, many resort to rote

teaching, prioritizing content coverage over conceptual understanding. Yet, in communities where teachers take initiative—crafting their own examples, co-teaching with local experts, or translating content into local idioms—students exhibit deeper engagement (Heilporn, Lakhal, & Bélisle, 2021). These innovations, while often informal and unsupported, demonstrate the latent capacity within the system for culturally responsive transformation.

Institutional Pressure to Conform to National Assessments at the Cost of Local Relevance

National assessments remain the dominant benchmark for academic success, shaping both instruction and curriculum priorities (Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002). This pressure often sidelines efforts to contextualize learning, as teachers feel compelled to “*teach to the test*”. Consequently, even culturally sensitive educators find themselves sacrificing relevance for performance metrics. However, some educational programs have piloted localized assessments or integrated ethnomathematical components into mainstream evaluations, showing that it is possible to measure learning without compromising cultural validity. These initiatives challenge the dichotomy between standardization and contextualization, suggesting that the two can coexist with thoughtful design and inclusive policymaking.

Reimagining the Future of Mathematics Learning

Across studies, there is a forward-looking momentum among educators and communities to redefine what mathematics education could and should look like in culturally diverse settings. As educational landscapes evolve, so too does the vision for what mathematics learning could become. A number of studies signal a paradigm shift—from reactive inclusion of cultural content to proactive redefinition of the purpose, form, and function of mathematics education (Gnawali, 2024). Communities and educators are not just adapting to dominant systems; they are reimagining new ones, grounded in cultural heritage, technological relevance, and collective empowerment.

This future-oriented momentum is both imaginative and strategic. It is imaginative in its aspirations to produce culturally-rooted learners who can serve as change agents, and strategic in its call for policy reforms, localized curriculum design, and digital integration. By reframing mathematics as a tool for cultural preservation, civic participation, and innovation, this movement is charting a path toward equity that is not merely symbolic, but systemic. This theme invites a hopeful yet grounded vision for mathematics education. It recognizes that cultural responsiveness is not merely a remedial strategy, but a transformative framework. Through digital tools, policy shifts, and leadership development, communities are not just surviving the educational system—they are reshaping it. The future of mathematics lies not in erasing difference, but in embracing it as a source of strength and innovation.

Integration of Digital Technologies with Indigenous Knowledge

Digital tools—ranging from educational applications to community-made videos—are being leveraged to document, teach, and celebrate indigenous mathematical practices (Viberg, Grönlund, & Andersson, 2020). These

technologies serve as both archival and instructional media, ensuring that localized knowledge systems are not only preserved but also scaled and shared. Rather than importing foreign content, some educators are co-creating digital materials with local artisans, farmers, and elders. These efforts ensure authenticity and relevance while also building digital literacy among learners (Lember, Brandsen, & Tönurist, 2019). The result is a convergence of tradition and innovation—where tablets and smartphones become vessels for ancestral wisdom.

Advocacy for Policy Reforms to Support Localized Curriculum Development

Policy-level interventions are increasingly seen as necessary to institutionalize culturally responsive practices. Researchers, educators, and community leaders are engaging with policymakers to advocate for flexible standards, culturally inclusive content, and recognition of ethnomathematical approaches in national frameworks (Aguayo et al., 2023). While progress remains uneven, some regions have piloted inclusive curriculum models or introduced training modules on cultural pedagogy in teacher education programs (Aronson & Laughter, 2016). These developments point toward the possibility of systemic change—where culturally-rooted education is not the exception, but the norm.

Emphasis on Producing Culturally-Rooted Future Learners and Educators

The ultimate goal of many culturally responsive mathematics initiatives is to cultivate a new generation of scholars and educators who are both mathematically adept and culturally grounded (Menzies, Schunn, & Stein, 2024). These individuals can serve as bridges between worlds—advancing STEM fields while honoring their communities' ways of knowing. Studies emphasize that when students see role models who share their linguistic, cultural, and epistemological backgrounds, they are more likely to pursue mathematical pathways (Di Lonardo Burret et al., 2022). This reimagining of mathematics education is not only about inclusion; it is about transformation—where the field itself becomes more diverse, equitable, and reflective of global plurality.

Discussion

The findings of this metasynthesis illuminate the evolving and multifaceted nature of mathematics learning spaces within cultural enclaves. This study underscores how culture, space, pedagogy, and policy intersect to shape both present practices and future possibilities. This metasynthesis contributes to the growing body of research that advocates for decolonizing mathematics education. This validates the lived experiences of learners and educators in marginalized communities while offering a hopeful, practical vision for transforming mathematics learning spaces into sites of cultural resilience and educational innovation. Four key discussion points are outlined below.

From Cultural Marginalization to Cultural Centrality

Historically, formal mathematics education in many cultural enclaves has marginalized indigenous knowledge systems, treating them as irrelevant or inferior. However, the reviewed studies collectively advocate for a paradigm shift toward cultural centrality—where learners' cultural experiences are not only acknowledged but

also leveraged as valid mathematical resources. This shift challenges dominant narratives of universality in mathematics by foregrounding ethnomathematical practices, demonstrating that mathematics is not monolithic but culturally inflected. The implications are profound that when learners see their traditions reflected in mathematics instruction, they engage more deeply, perform more confidently, and develop a stronger sense of identity as mathematical thinkers.

Learning Spaces as Dynamic Ecosystems

The notion of the classroom as the sole or primary site of learning is increasingly inadequate in cultural contexts where learning is distributed, embodied, and communal. Studies in this synthesis highlight that in cultural enclaves, mathematical ideas emerge in marketplaces, kitchens, forests, farms, and ceremonies. These learning ecosystems are dynamic, with knowledge flowing between formal and informal contexts. As such, educators and policymakers must begin to reconceptualize learning spaces—not as bounded locations, but as networks of interaction across physical, social, and cultural dimensions. Future learning spaces must embrace this fluidity to remain relevant.

Navigating Tensions: Standardization vs. Localization

One of the most persistent issues across the studies is the tension between standardized curricula, which prioritize universal benchmarks and assessment metrics, and localized learning needs, which prioritize cultural resonance and contextual learning. While national standards aim to ensure equity and mobility, they can inadvertently exclude or undervalue localized knowledge systems. However, this tension is not insurmountable. The synthesis reveals creative pedagogical strategies where teachers blend national standards with local content, forming hybrid approaches that maintain both rigor and relevance. This finding suggests a need for greater curricular flexibility, teacher autonomy, and support structures that empower local stakeholders to co-construct mathematics curricula in ways that reflect both global and local imperatives.

Future-Proofing Mathematics Education in Cultural Enclaves

Looking ahead, the studies point toward a promising trajectory in which mathematics education in cultural enclaves becomes innovative, inclusive, and future-oriented. Community-driven initiatives, use of technology, and grassroots curriculum development efforts signal an emergent model of education that is responsive to both cultural heritage and 21st-century skills. The Juxtaposed Progression Lattice (JPL) Model developed from this metasynthesis encapsulates the evolution that mathematics education is not a static process, but one that continually loops through affirmation, adaptation, negotiation, co-engagement, and visioning. This cyclical yet progressive movement ensures that change is grounded in cultural continuity, not disconnection.

Emergent Model

From the results, a synthesis model emerged—the *Juxtaposed Progression Lattice (JPL) Model*—representing

the future of mathematics learning in cultural enclaves as cyclical yet ascending (see Figure 2). The model offers a robust conceptual framework for understanding the evolving dynamics of mathematics learning in cultural enclaves. Rather than positioning educational change as a linear trajectory, the JPL Model conceptualizes it as a lattice—cyclical in rhythm, yet progressively ascending. This reflects the iterative and recursive nature of transformation, where each cycle begins with a renewed affirmation of cultural identity. By foregrounding *cultural affirmation* as the model's foundational phase, the JPL underscores that any meaningful shift in mathematics education needs to begin with the reclamation and validation of indigenous knowledge systems. Here, learners and educators re-anchor their epistemic identities, restoring the ontological grounding often erased by colonial curricula. It is through this deliberate reconnection with cultural roots that mathematics becomes a living language of heritage, not merely a neutral tool of abstraction.

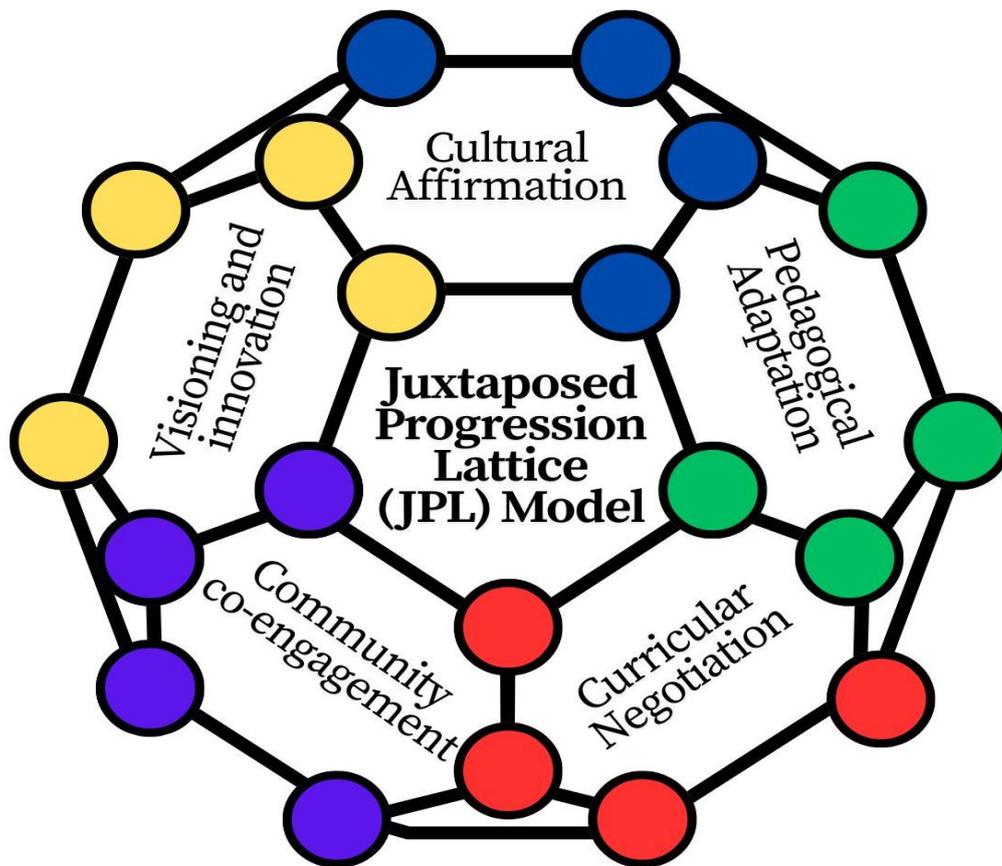


Figure 2. Juxtaposed Progression Lattice (JPL) Model

Following this re-rooting, the model advances into *pedagogical adaptation* and *curricular negotiation*, where teaching approaches are restructured and curricular content is recalibrated. Pedagogical adaptation reflects the creative capacity of educators to weave together traditional oral literacies, community narratives, and modern instructional strategies in ways that resonate with learners' lifeworld. Curricular negotiation, in turn, involves mediating the friction between imposed standards and locally relevant content—a process that requires both critical reflexivity and institutional courage. These stages are not only technical tasks but political acts, wherein educators and communities assert their agency to define what counts as mathematical knowledge. By situating these phases within a continuous spiral, the JPL Model acknowledges that adaptation and negotiation are not one-time interventions but ongoing, responsive dialogues across cycles.

Crucially, the lattice ascends through *community co-engagement* and culminates in *visioning and innovation*, where the future is not simply awaited but actively constructed. Community co-engagement mobilizes the collective wisdom of elders, parents, and local leaders, transforming learning spaces into intergenerational and intersubjective ecosystems. It decentralizes authority and legitimizes alternative modalities of teaching and assessment rooted in lived experience. The visioning phase, meanwhile, opens space for imagination—where learners and educators co-create tools, policies, and epistemologies that transcend existing binaries between the traditional and the modern. By holding these five phases in dynamic tension, the JPL Model does not prescribe a fixed path but provides a scaffold for recursive and culturally-situated progress. It redefines mathematics education as an emancipatory project—where relationality, reflexivity, and rootedness converge to shape a more just and plural future.

Conclusion

This metasyntesis explored the future trajectory of mathematics learning spaces in cultural enclaves through the integration and analysis of 28 qualitative studies. The findings affirm that mathematics education in culturally diverse contexts is neither fixed nor culturally neutral—it is dynamic, situated, and deeply influenced by the social, historical, and epistemological contexts in which it occurs. Together, these four themes articulate a coherent and compelling case for a culturally-responsive mathematics education—one that is grounded, fluid, transformative, and future-oriented. The studies reviewed reveal not isolated innovations, but interconnected patterns of resistance, adaptation, and reimagination across diverse cultural contexts. What emerges is a holistic framework where mathematics is not divorced from culture but is animated by it.

By integrating indigenous epistemologies, flexible pedagogies, critical curricular engagement, and visionary future planning, mathematics education can become a space of empowerment rather than marginalization. It can nurture not only numerate individuals, but culturally confident and critically engaged citizens capable of navigating and reshaping the world. In this reimagined landscape, mathematics is no longer just a subject—it is a dialogue between worlds, a bridge across generations, and a pathway toward equity. Mathematics learning in cultural enclaves holds the potential not only to nurture culturally grounded mathematical thinkers, but also to reshape the broader landscape of education. This future is not a return to the past, but a spiral movement forward, where tradition and transformation coalesce to create mathematics education that is empowering, relevant, and just.

Recommendations

A culturally responsive mathematics education system cannot be achieved through pedagogical change alone—it requires a rethinking of structural, curricular, and policy foundations. One critical pathway is through curriculum development that actively recognizes and incorporates ethnomathematical knowledge systems. These are not peripheral curiosities, but robust intellectual traditions that deserve legitimacy within national education frameworks. Co-creating curricular materials with cultural elders, local educators, and knowledge holders ensures that problem-solving contexts are culturally meaningful and identity-affirming. Such collaboration not only

enriches content but also democratizes curriculum authority, bridging the gap between centralized education systems and community epistemologies. This transformation calls for policies that embed cultural sustainability into the very architecture of curriculum design.

Equally vital is the professional development of educators, who serve as the frontline implementers of culturally grounded curricula. Teacher training programs may include sustained exposure to ethnomathematical perspectives, intercultural pedagogy, and localized curriculum adaptation. Such preparation equips teachers to navigate the often-unspoken tension between standardized curricular demands and the lived realities of learners in cultural enclaves. Simultaneously, reimagining learning spaces as hybrid environments—where digital technologies, oral traditions, and intergenerational knowledge intersect—enables education to unfold in both formal and informal settings. This requires participatory governance models where communities are not passive recipients but co-architects of education policy and practice. Future-oriented planning may support interdisciplinary research, educational innovations, and long-term impact studies to track how culturally responsive mathematics education reshapes learner identities, community resilience, and national development over time. In this broader policy ecosystem, culture is not a constraint—it is a generative force in educational transformation.

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