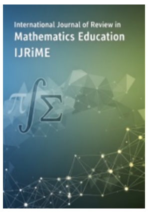

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Multiple Mathematical Representations in Ethnomathematics-Based Realistic Mathematics Education: A Systematic Literature Review

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Abstract

Research on ethnomathematics-based Realistic Mathematics Education (Ethno-RME) has grown significantly in recent years, particularly in relation to its potential to support meaningful and culturally grounded mathematics learning. However, there remains limited systematic understanding of how multiple mathematical representations function within this framework, especially in facilitating representational transitions and conceptual understanding. This study aims to synthesize and analyze research on Multiple Mathematical Representations (MMR) within Ethno-RME through a Systematic Literature Review. The review identifies the types of representations employed, their roles in the mathematization process, and their contributions to mathematics learning outcomes. A systematic procedure consisting of planning, conducting, and reporting stages was implemented. Articles were retrieved from the Scopus database using the Publish or Perish tool and selected based on predefined inclusion and exclusion criteria, resulting in ten eligible peer-reviewed studies published between 2016 and 2025. The findings indicate that Ethno-RME consistently promotes the development and coordination of multiple representations, including visual, symbolic, verbal, contextual, and technological forms. Cultural contexts function as meaningful entry points that initiate representational construction and facilitate the transition from informal situational models to formal mathematical abstraction through progressive mathematical mathematics. The synthesis further reveals that representational coordination enhances conceptual understanding, problem-solving ability, numeracy skills, creativity, and higher-order thinking. Moreover, mathematical representation emerges as a bridge linking contextual experience and formal reasoning. Overall, this review establishes that multiple mathematical representations constitute a foundational mechanism within ethnomathematics-based RME, supporting meaningful, culturally grounded, and conceptually robust mathematics learning.

Keywords: Ethnomathematics, Multiple Mathematical Representations, Realistic Mathematics Education, Systematic Literature Review

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1. Introduction

Mathematics education continues to face persistent challenges in fostering deep conceptual understanding among students (Ayeh., 2025). Instruction often emphasizes procedural fluency and symbolic manipulation without ensuring that learners construct meaningful interpretations of mathematical ideas (Ernie et al., 2023; Hadi et al., 2025). Such conditions lead students to perform routine tasks successfully while struggling to interpret concepts presented in unfamiliar forms or real-world situations (Gebremeskel et al., 2025). This gap between formal procedures and conceptual meaning indicates the need for learning approaches that support sense-making and knowledge construction (Rittle-Johnson and Siegler, 1998).

Mathematical understanding develops through the use of representations that express ideas in multiple forms (Jäder and Johansson, 2025). Mathematics concepts may be communicated through visual diagrams, verbal explanations, symbolic notation, tables, graphs, physical models, or contextual situations (Mainali, 2020). The ability to coordinate and translate among these forms determines the depth and flexibility of students' understanding (Utomo and Syarifah, 2021). Limitations in representational competence often result in fragmented knowledge and superficial learning.

Multiple mathematical representations provide a framework for viewing representations as cognitive tools rather than mere instructional aids (Mainali, 2020). Representations function to support reasoning, meaning-making, and abstraction when learners actively connect different forms (Ahmar and Azzajjad, 2025). Learning environments rich in representations allow students to move gradually from intuitive experiences to formal mathematical structures (Alyanak and Özkaya, 2026). This representational diversity becomes crucial in bridging concrete experiences and abstract reasoning (Wahyuningrum et al., 2025).

Context plays a fundamental role in shaping how mathematical representations gain meaning (Divis et al., 2025). Representations grounded in familiar situations enable students to anchor abstract ideas in lived experience (Savard, 2020). Cultural practices, daily activities, and community knowledge contain implicit mathematical structures that can serve as meaningful starting points for learning (Sunzuma and Maharaj, 2020). Meaningful contexts therefore provide an epistemological foundation for developing initial representations before formal symbolism is introduced.

Ethnomathematics views mathematics as a human activity embedded in cultural practices and social realities (Rosa et al., 2016). Cultural artifacts, traditional designs, measurement systems, and problem-solving strategies embody mathematical ideas developed within communities(Abdullah et al., 2025; Anriana et al., 2023). Incorporating such contexts into instruction allows students to see mathematics as relevant and connected to their environment. Cultural grounding enriches representational forms by linking mathematical meaning with social and experiential dimensions (Dreher et al., 2024).

Realistic Mathematics Education (RME) offers a pedagogical approach that emphasizes learning through meaningful contexts and progressive formalization (Alim et al., 2020; Fajri, Marini, and Suyono, 2025; Fredriksen, 2020; Heuvel-Panhuizen and Drijvers, 2020). Students engage in mathematization processes that begin with real situations and evolve toward formal mathematical concepts (Fajri et al., 2025). Models and representations function as bridges that connect contextual problems to symbolic reasoning (Kartini et al., 2025). The transition from informal strategies to structured mathematical forms highlights the central role of representations within RME (Freudenthal, 2002; Sari et al., 2025).

While the integration of RME and ethnomathematics offers promising opportunities for culturally responsive mathematics learning, it also introduces inherent pedagogical tensions. RME is rooted in guided reinvention, which promotes a structured pathway toward formal abstraction, whereas ethnomathematics emphasizes culturally embedded practices that are often informal, context-dependent, and not always aligned with standardized mathematical representations. Consequently, integrating these frameworks requires careful negotiation between preserving cultural meaning and facilitating formal mathematical generalization. To address these tensions, the integration of ethnomathematics and RME can be understood through a representational approach, where cultural contexts serve as the starting point for learning, and guided reinvention provides the structure for progressive mathematization. In this process, students initially engage with culturally meaningful representations, which are then gradually transformed into more formal mathematical representations through carefully designed instructional sequences.

Ethnomathematics-Based Realistic Mathematics Education (Ethno-RME) extends conventional RME by embedding culturally situated contexts as the starting point of the mathematization process. While standard RME utilizes real-life situations to introduce mathematical ideas, Ethno-RME specifically incorporates cultural artifacts, practices, and local knowledge systems, resulting in a richer and more diverse set of initial representations. This integration not only enhances the meaningfulness of learning but also increases the complexity of representational transitions, as students must translate culturally grounded, often informal representations into formal mathematical structures.

The integration of ethnomathematical contexts with RME creates learning environments where culture-based situations initiate the process of mathematization (Cesaria et al., 2022). Cultural representations provide the starting point, models serve as intermediaries, and formal symbols become the endpoint of abstraction. This integration naturally involves the use of multiple representations that evolve throughout the learning process (Ainsworth, 1999). However, previous studies have not systematically examined how multiple representations function across different stages of mathematization within Ethno-RME, particularly in terms of (1) representational transitions from cultural-contextual forms to formal mathematical structures, (2) the role of technological tools in shaping these transitions, and (3) the extent to which representations contribute to cognitive processes such as problem solving and conceptual understanding.

A comprehensive synthesis of existing research is therefore necessary to understand the role of multiple representations in ethnomathematics-based RME. Identifying the types of representations used, their functions in mathematization, and their impact on learning can clarify theoretical and pedagogical relationships among these domains. Such analysis can reveal patterns, strengths, and gaps in current research. In addition, this study also explores how multiple mathematical representations may function as cognitive links that connect contextual experiences with formal mathematical reasoning, providing a deeper understanding of their role within the mathematization process.

2. Method/Approach

A Systematic Literature Review (SLR) method was implemented in this study to integrate findings related to multiple mathematical representations in ethnomathematics-based Realistic Mathematics Education. The SLR was carried out through a systematic and replicable process involving three principal stages: planning, conducting, and reporting, as shown at **Figure 1**.

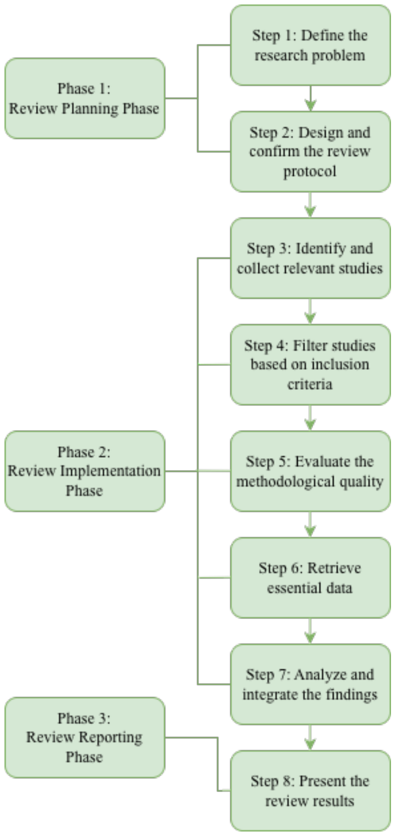

Figure 1. Stages of Systematic Literature Review (Xiao and Watson, 2017)

The initial phase of the review was Planning, which involved defining the research question. The guiding question focused on how multiple mathematical representations in ethnomathematics-based Realistic Mathematics Education have been implemented in mathematics learning between 2016 and 2025, particularly in terms of research participants, methods, and findings. During this phase, a review protocol was established by determining the search strategy and relevant keywords, including “mathematical representations,” “multiple mathematical representations,” “ethnomathematics,” “ethnomathematics-based RME,” and “RME local wisdom.” Scopus was selected as the primary database for retrieving literature. The search strategy was constructed using Boolean operators to ensure comprehensive and systematic retrieval of relevant studies. The following search string was applied in the Scopus database: ("multiple mathematical representation" OR "mathematical representation") AND ("ethnomathematics") AND ("realistic mathematics education" OR "RME" OR "ethno-RME").

The second phase was Conducting the Review, which involved executing the literature search and collecting potentially relevant studies. The search process was supported by the Publish or Perish (PoP) software to retrieve indexed articles from the Scopus database. This study utilized the Scopus database due to its comprehensive coverage of high-quality, peer-reviewed international publications. A quality assessment was conducted to evaluate the methodological rigor of the selected studies. This process aimed to ensure that only studies with sufficient credibility and relevance were included in the synthesis. The assessment was based on predefined criteria, including the clarity of research objectives, appropriateness of the research design, rigor of data collection methods, validity of data analysis, and relevance to the focus on multiple mathematical representations within Ethno-RME contexts. Studies were

Table 1. Criteria Formulated of Inclusion Criteria and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
IC1. Disciplinary Scope: Studies conducted within the domain of mathematics education.	**EC1.** Research situated outside mathematics education (e.g., engineering training or general pedagogy without a mathematical focus).
IC2. Research Focus: Studies investigating ethnomathematics or learning grounded in ethnomathematics-based Realistic Mathematics Education.	**EC2.** Studies that do not address ethnomathematics or ethnomathematics-based RME in learning contexts.
IC3. Study Design: Empirical investigations employing quantitative, qualitative, mixed-methods, or systematic literature review approaches that report actual instructional or learning data.	**EC3.** Purely conceptual or theoretical works, meta-analyses, editorials, and opinion-based publications.
IC4. Publication Type: Articles published in peer-reviewed journals or conference proceedings.	**EC4.** Books, book chapters, reviews, theses, dissertations, institutional reports, or unpublished documents.
IC5. Language: Publications written in English.	**EC5.** Publications in languages other than English.
IC6. Data Source: Studies indexed in the Scopus database and retrieved through the Publish or Perish tool.	**EC6.** Studies not indexed in the selected database.
IC7. Publication Period: Studies published within the defined review period (2016–2025).	**EC7.** Studies published outside the specified time span.

considered eligible if they addressed multiple mathematical representations and ethnomathematics-based RME and were published between 2016–2025.

The review focuses on studies published between 2016 and 2025. The starting point of 2016 was selected to capture contemporary developments in mathematics education research, particularly the increasing integration of ethnomathematics and Realistic Mathematics Education in recent years. This period reflects a shift toward culturally responsive pedagogy and the growing emphasis on the use of multiple representations in supporting conceptual understanding. Following the identification of relevant records, the study established explicit study selection criteria to determine the suitability of articles for further analysis. These criteria were formulated as inclusion criteria (IC) and exclusion criteria (EC) to ensure alignment between the selected studies and the objectives of the review. A detailed description of the IC and EC is provided at **Table 1**.

The exclusion criteria included studies that were not written in English, not focused on ethnomathematics or RME, or did not address mathematical representations. In addition, meta-analyses were excluded from this review to maintain a focus on primary empirical studies. This allows for a more direct examination of how multiple mathematical representations are implemented and function within Ethno-RME learning contexts. The final phase, Reporting the Review consisted of a comprehensive analysis of the ten selected studies, focusing on research participants, methods, and findings. The selection of articles was guided by predefined inclusion and exclusion criteria, which are detailed in **Table 1**. The study selection process was conducted systematically following the PRISMA guidelines to ensure transparency and methodological rigor (Putri et al., 2025; Santosa et al., 2026). The detailed stages of identification, screening, eligibility assessment, and final inclusion of studies are presented in the PRISMA flowchart in **Figure 2**.

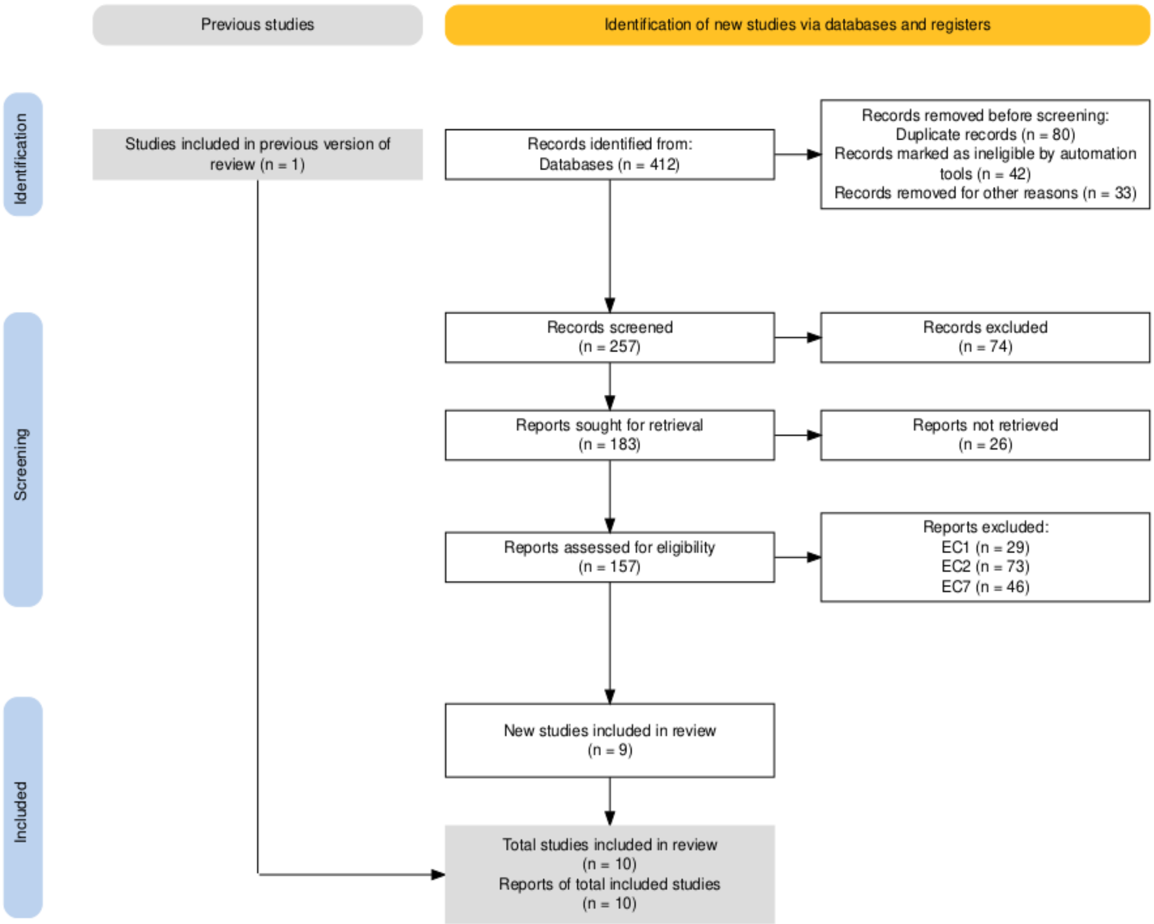

Figure 2. PRISMA Flow Diagram of the Study Selection Process

The relatively small number of selected studies reflects the emerging and specialized nature of research at the intersection of ethnomathematics, realistic mathematics education, and multiple representations. The strict inclusion criteria applied in this review were intended to ensure the relevance and quality of the selected studies. The quality assessment was conducted using a set of predefined criteria adapted from previous systematic review studies. These criteria included the clarity of research objectives, appropriateness of the research design, rigor of data collection methods, validity of data analysis, and relevance of findings to the research focus. Each study was systematically evaluated based on these criteria to ensure the credibility and reliability of the synthesized results.

3. Results and Discussion

The essential information from each study is summarized, including the authors, year of publication, research title, and the main conclusions relevant to the role of multiple representations in ethnomathematics-based RME. This synthesis serves as the foundation for identifying patterns, strengths, and research gaps across literature. The summary of review studies is presented at Table 2.

Table 2. Summary of Review Studies

No.	Authors and Year	Research Title	Research Conclusion
1.	Andzin et al., 2024	Arithmetic Sequences and Series Learning Using Realistic Mathematics Education Assisted by Augmented Reality	Ethnomathematics-based RME using the Borobudur context enhances students' conceptual understanding of arithmetic sequences and series by supporting the transition from cultural-contextual representations to formal mathematical representations.
2.	Nursyahidah, 2025	Integrating Technology, Ethnomathematics, and Realistic Mathematics Education in Learning Statistics: A Learning Trajectory	Ethnomathematics-based Technology-Enhanced RME using the pranata mangsa context enhances students' conceptual understanding of statistics by guiding the transition from cultural-contextual representations to formal statistical representations through technology-supported learning.
3.	Febrian & Astuti, 2018	The RME Principles on Geometry Learning with Focus of Transformation Reasoning through Exploration on Malay Woven Motif	Ethnomathematics-based RME using Malay woven motifs enhances students' conceptual understanding of transformation geometry by supporting reasoning through meaningful contextual and visual representations.
4.	Yuanita et al., 2018	The Effectiveness of Realistic Mathematics Education Approach: the Role of Mathematical Representation as Mediator Between Mathematical Belief and Problem Solving	RME improves students' mathematical belief, representations, and problem-solving skills by facilitating idea construction from real-life contexts, highlighting the importance of strengthening representation-focused instruction.
5.	Muhammad et al., 2018	Implementation of Ethnomathematics Realistic Mathematics Education (Ethno-RME) in Mathematics Learning: Systematic Literature Review (SLR)	Ethno-RME effectively improves students' conceptual understanding, representations, communication, problem solving, and critical thinking by integrating cultural contexts into RME-based mathematics learning and teaching material development.
6.	Bicer, 2021	Multiple Representations and Mathematical Creativity	Multiple mathematical representations improve pre-service teachers' mathematical creativity and serve as effective tools for both fostering and assessing creative thinking in mathematics.
7.	Nursyahidah et al., 2025	Integrating technology, Javanese ethnomathematics, and realistic mathematics education in supporting prospective mathematics teachers' numeracy skills: A learning trajectory	Ethnomathematics-based Technology-Enhanced RME with digital media improves pre-service teachers' numeracy understanding by supporting the transition from cultural-contextual representations to formal mathematical representations.
8.	Fitria et al., 2025	Investigation of the impact online single and multiple representation scaffolding on mathematical concept mastery and mathematical problem-solving skill	Integrating textual and visual representations in dual scaffolding improves students' conceptual understanding and problem-solving by strengthening cognitive processing through coordinated multiple representations.
9.	Ott et al., 2018	Multiple symbolic representations: The combination of formula and text supports problem solving in the mathematical field of propositional logic	Multiple symbolic representations integrating text and formulas effectively enhance problem solving and support the development of theory and design in multiple-representation learning environments.
10.	Kang & Liu, 2016	The Importance of Multiple Representations of Mathematical Problems: Evidence from Chinese Preservice Elementary Teachers' Analysis of a Learning Goal	Cross-cultural findings show shared challenges in teacher preparation and suggest that integrating complementary practices, analogous to coordinating multiple representations, strengthens mathematics teaching development.

While Table 2 summarizes the key findings across studies, a closer examination reveals several important patterns and variations. Across the reviewed literature, multiple representations consistently function as a bridge between contextual understanding and formal mathematical reasoning. However, the effectiveness of these representations varies depending on instructional design, student readiness, and the nature of the learning context. A notable distinction emerges between studies utilizing technological tools and those relying on traditional physical artifacts. Technology-enhanced representations allow for more dynamic and interactive translation processes, enabling students to manipulate and visualize mathematical concepts in real time. In contrast, traditional physical artifacts tend to support more static representations, where the transformation between representations relies more heavily on teacher guidance and student interpretation.

Based on the synthesis of the ten selected studies, this systematic literature review confirms that Ethnomathematics-Based Realistic Mathematics Education has a strong and consistent impact on the development of multiple mathematical representations. However, it is important to note that most of the reviewed studies are situated within specific cultural contexts, particularly in Indonesia. Therefore, the generalizability of these findings to other cultural settings may be limited. Across different mathematical domains and participant groups, Ethno-RME supports learners in transforming cultural-contextual representations into formal mathematical representations, demonstrating a structured representational progression aligned with the principle of progressive mathematization (Andzin et al., 2024; Nursyahidah et al., 2025; Nursyahidah et al., 2025). The reviewed studies show that cultural artifacts and practices serve as initial representational anchors that help learners build meaning before engaging in symbolic abstraction.

Several studies demonstrate that ethnomathematical contexts promote the coordinated use of visual, contextual, verbal, symbolic, and technological representations. A critical pattern identified across the reviewed studies is that the transition from contextual to symbolic representations appears to be the most cognitively demanding stage. At this stage, students are required to move beyond concrete, culturally grounded experiences and reconstruct meaning within abstract symbolic systems. This process involves not only translation between representations but also conceptual reorganization, which often leads to misunderstandings if sufficient scaffolding is not provided. Learning designs based on Borobudur temple architecture enabled students to move from spatial–visual representations toward algebraic generalizations in sequences and series (Andzin et al., 2024). Similarly, geometry learning through Malay woven motifs facilitated transformation reasoning through pattern-based visual representations prior to formal symbolic modeling (Febrian and Astuti, 2018). In statistics education, the integration of pranata mangsa cultural knowledge within technology-enhanced RME environments supported students in linking contextual interpretations with graphical and numerical representations (Nursyahidah et al., 2025). These findings indicate that Ethno-RME structures representation as a learning trajectory rather than as an isolated outcome.

The reviewed literature also provides strong evidence that multiple representations function as a central cognitive mechanism supporting conceptual understanding and problem solving. Ethno-RME environments encourage learners to shift flexibly among diagrams, texts, symbols, and contextual models, which strengthens cognitive processing and conceptual mastery (Fitria et al., 2025; Ott et al., 2018). Studies on representation scaffolding further show that integrating textual and visual supports enhances students' ability to coordinate representations, reducing cognitive overload and improving conceptual transfer (Fitria et al., 2025). This suggests that representation coordination, rather than single-mode representation, is the critical instructional feature.

Several studies highlight the mediating role of mathematical representation within the Ethno-RME framework. Research indicates that representation bridges students' beliefs, understanding, and problem-solving performance. RME-based instruction improves students' representational competence, which in turn strengthens mathematical reasoning and higher-order thinking (Muhammad et al., 2025; Yuanita et al., 2018). The integration of cultural contexts reinforces this mediation process by providing meaningful situational models that support abstraction and generalization.

The importance of multiple representations is also evident in teacher education contexts. Studies involving pre-service teachers show that engagement with multiple mathematical representations enhances numeracy understanding, creativity, and pedagogical awareness (Bicer, 2021; Kang and Liu, 2018; Nursyahidah et al., 2025). These findings suggest that representational competence is not only a student learning outcome but also a professional competency necessary for designing meaningful mathematics instruction.

Overall, the findings across the reviewed studies consistently indicate that Ethnomathematics-Based RME is an effective framework for fostering multiple mathematical representations. Its effectiveness is evident across content areas, learner levels, and instructional modalities, including technology-enhanced environments. Ethno-RME facilitates a coherent representational progression from cultural and experiential models to formal symbolic systems making it a robust approach for supporting deep conceptual understanding and representational fluency in mathematics learning (Andzin et al., 2024; Fitria et al., 2025; Muhammad et al., 2025).

4. Conclusion

This systematic literature review synthesizes research published between 2016 and 2025 on Multiple Mathematical Representations within Ethnomathematics-Based Realistic Mathematics Education. The findings consistently indicate that Ethno-RME provides a structured and meaningful framework for developing students' ability to construct and coordinate multiple representations, including visual, symbolic, verbal, contextual, and technological forms. Across various mathematical topics and participant groups, cultural contexts function as representational entry points that support the transition from informal situational models to formal mathematical abstractions, reflecting the principle of progressive mathematical mathematics.

The review further demonstrates that multiple representations act as central cognitive mediators in the learning process. Rather than functioning as isolated instructional aids, representations in Ethno-RME evolve dynamically throughout the mathematization process, strengthening conceptual understanding, problem-solving ability, and higher-order thinking. The coordination and translation among representations emerge as key indicators of deep mathematical understanding. Additionally, the integration of technology and teacher education contexts expands the representational landscape, reinforcing the role of representational competence as both a student learning outcome and a professional teaching competency.

Overall, this review establishes that Multiple Mathematical Representations are a foundational mechanism through which Ethnomathematics-Based RME promotes meaningful and culturally grounded mathematics learning. Future research is encouraged to examine representational transitions more explicitly and to explore longitudinal and cross-cultural implementations to further strengthen the theoretical and pedagogical foundations of Ethno-RME.

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Declarations

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