

Unveiling Cognitive Dynamics and Classroom Culture: A Literature Review of Qualitative Research in Mathematics Education

Fadhlor Rohman¹, Lulu Sekardini², Nadila³, Arvina Tri Septiani⁴, Sri Hastuti Noer⁵, Agung Putra Wijaya^{6*}
^{1,2,3,4,5,6}Lampung University
*) agung.wijaya@fkip.unila.ac.id

Abstract

This study aims to analyze the contribution of qualitative research approaches, particularly ethnography and case studies, in unveiling the interplay between classroom culture and students' mathematical thinking processes. Using a literature review method, this study synthesizes scholarly sources from 2015 to 2025 to deepen the understanding of how social context influences cognitive construction in mathematics education. The findings reveal that mathematical thinking is not an isolated cognitive activity but is deeply embedded in classroom culture. Ethnographic approaches effectively uncover the "hidden curriculum" and cultural norms that shape learning, while case studies provide granular insights into students' specific cognitive hurdles. The integration of these approaches with constructivist pedagogies, such as Realistic Mathematics Education (PMRI), offers a robust framework for creating more meaningful and culturally responsive learning environments. This study concludes that qualitative inquiry is essential for bridging the gap between individual cognition and social context, providing a humanistic perspective on mathematics education.

Keywords: qualitative research, classroom culture, mathematical thinking, ethnography, mathematics education

Introduction

In the last decade, understanding cognitive dynamics and classroom culture through qualitative research has experienced significant development. This approach, rooted in the behaviorist perspective that emphasizes social interaction, is increasingly used to understand how students' thinking processes are shaped by their environment (Fanggidae et al., 2024). In Indonesia, low student achievement in international assessments such as the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) indicates that students' mathematical thinking skills and numeracy literacy still require serious attention (Jazilah, 2024; Yuda & Rosmilawati, 2024). This condition demands the implementation of learning approaches that are more meaningful, contextual, and oriented toward students' real-life experiences.

The foundation for understanding students' mathematical thinking lies in behaviorism, which emphasizes how social interactions in the classroom contribute to students' mathematical understanding. One approach that has been widely researched and proven effective in facilitating meaningful learning is Realistic Mathematics Education (RME), or known in Indonesia as Pendidikan Matematika Realistik Indonesia (PMRI),

which emphasizes the connection between mathematical concepts and the context of students' daily lives (Fitriyana & Elly, 2025; Sade et al., 2025). Thus, qualitative research becomes essential to capture the shift in classroom culture and understand how students construct mathematical meaning within this contextual framework.

Although various efforts have been made to improve the quality of mathematics learning and learning design, classroom practices often face challenges in bridging abstract concepts with social realities and students' concrete experiences. Deep mathematical thinking processes depend not only on individual cognitive abilities but also on social interactions, language, and classroom culture that shape the meaning of mathematics learning (Ayu, 2023; Irawan et al., 2025). There is a significant challenge for educators to integrate these cultural aspects to support learning, causing the sociocultural dimension to often be overlooked in the design of learning activities. Therefore, analyzing cognitive dynamics within the classroom culture is essential to explore how these interactions, values, and meanings shape students' mathematical construction.

Mathematics learning characterized by constructivism emphasizes the construction of self-understanding actively, creatively, and productively based on prior knowledge and experience (Mufti, 2025). Knowledge is not a set of facts and concepts ready to be received, but rather something that must be constructed by students themselves through interaction with their learning environment. Therefore, a qualitative approach is needed to explore in depth the dynamics of interaction, values, and meanings that emerge in mathematics learning practices.

Various ethnographic and case studies in mathematics education have shown that social and cultural contexts have a significant influence on how students understand and interpret mathematical concepts (Azmi, 2024; Sukirwan et al., 2023). Previous studies have confirmed that PMRI can improve students' critical thinking skills, mathematical representation, and numeracy literacy. However, most of these studies remain fragmentary, with separate focuses on analyzing mathematical thinking processes and examining classroom culture. Simultaneous and in-depth integration of the two is still rarely undertaken. For example, Azmi (2024) examined ethnomathematics in Acehese culture, while Sukirwan et al. (2023) explored ethnomathematics research trends in Indonesia, yet few studies systematically combine cognitive and cultural analyses.

The main gap in previous research lies in the inadequate integration of approaches that combine student cognitive analysis with the sociocultural context of the mathematics

classroom (Mulbasari et al., 2024). Most studies are still limited to descriptions of learning behavior without developing conceptual models that explain the reciprocal relationship between culture, social interaction, and mathematical cognition. This results in limited theoretical understanding and practical implications for developing effective pedagogical strategies. Another limitation is the lack of in-depth exploration of qualitative data through comprehensive triangulation between observations, interviews, and learning documents. Therefore, a literature review is necessary to synthesize these scattered findings into a cohesive understanding of how classroom culture specifically drives cognitive dynamics.

To address these limitations, this study proposes an integrated approach between ethnography and case studies as a methodological strategy to uncover the relationship between classroom culture and students' mathematical thinking processes. This approach allows researchers to understand the social dynamics and cultural meanings that influence students' cognitive processes in learning mathematics. In qualitative research, trustworthiness criteria including credibility, transferability, dependability, and confirmability serve as important standards to ensure the validity of findings (Lincoln & Guba, as cited in Creswell, 2018).

Thus, this study aims to examine in depth the contribution of qualitative approaches, particularly ethnography and case studies, in understanding students' mathematical thinking processes and uncovering the role of classroom culture in mathematics learning. The research questions guiding this inquiry are: (1) How do qualitative approaches such as ethnography and case studies contribute to understanding students' cognitive dynamics in mathematics learning? (2) What is the role of classroom culture in shaping students' mathematical understanding? (3) How can qualitative research findings inform the development of more culturally responsive mathematics curricula aligned with the Indonesian context? Theoretically, this research is expected to broaden the foundation for developing learning theories oriented toward the interaction between cognition and culture. Practically, the results of this study can provide insights for educators, researchers, and policymakers in designing mathematics learning that is more relevant, contextual, and rooted in the social realities of Indonesian students.

Method

This study employed a literature review method to synthesize scholarly sources on qualitative research in mathematics education, specifically examining how ethnographic and

case study approaches elucidate the relationship between classroom culture and students' mathematical thinking. This approach allows for a comprehensive analysis of empirical and theoretical insights from secondary resources to strengthen the research theme without requiring primary fieldwork (Nursalam, 2020).

Data were collected through flexible searches in academic databases such as Google Scholar and SINTA (Science and Technology Index) using keywords including "qualitative research," "mathematics education," "ethnography," "case study," "classroom culture," and "mathematical thinking." Priority was given to publications from the last decade (2015–2025) to ensure relevance (Fanggidae et al., 2024; Triandini et al., 2019). Literature was selected based on its focus on qualitative methodologies, its contribution to understanding cognitive and cultural dynamics in mathematics learning, and its credibility as peer-reviewed work (Choifah et al., 2022).

Data Analysis: Selected literature was analyzed using thematic analysis, a systematic technique for identifying, organizing, and reporting patterns and themes within qualitative data. The analysis process followed these steps: (1) thorough reading and familiarization with the selected sources, (2) initial coding to identify key concepts related to the research questions, (3) organization of codes into thematic categories aligned with the study's aims, and (4) synthesis and interpretation of themes to construct a coherent narrative.

Specifically, the analysis focused on three main themes derived from the research questions: (1) How qualitative approaches contribute to understanding cognitive dynamics examining types of qualitative approaches (ethnography, phenomenology, case study, grounded theory) and their effectiveness in revealing students' mathematical thinking processes; (2) How classroom culture shapes students' mathematical understanding analyzing data collection techniques (interviews, observation, document analysis) and how social interactions, values, and norms influence cognitive construction; and (3) Practical implications for curriculum development extracting findings related to trustworthiness criteria in qualitative research and recommendations for culturally responsive pedagogy aligned with the Indonesian context.

Findings were synthesized descriptively to construct a coherent narrative that connects methodological rigor with educational implications (Sukirwan et al., 2023). To ensure reliability and transparency, the review process involved cross-checking sources,

carefully documenting the selection and interpretation process, and maintaining reflexivity throughout the analysis (Creswell & Poth, 2018).

Results and Discussion

The qualitative approach in mathematics education plays an important role in understanding how students actually learn mathematics in the classroom. Through direct observation and in-depth interviews, researchers can see the strategies students use when solving problems, the difficulties they face, and how classroom culture influences their learning. For example, in learning using the PMRI approach, students are not only given formulas but are asked to create their own strategies using the context of their daily lives.

A key characteristic of qualitative research is that researchers are directly involved in collecting data in a natural way. Unlike written tests that only show correct or incorrect answers, qualitative research allows researchers to dig into the "why" behind each student's answer (Snyder, 2019). For instance, when a student makes a mistake in solving a problem, the researcher can directly ask what made the student think that way, whether it was due to a misunderstanding of the concept or because of the influence of how their classmates learn (Lim, 2025). With this approach, the data collected is far richer and more meaningful compared to relying only on test results (Ghamrawi et al., 2025).

In mathematics education, qualitative approaches include several types relevant for examining students' context and cognition, such as classroom ethnography, phenomenology, case study, and grounded theory (Stanley, 2024).

Creswell (2018) emphasized that these four approaches are not mutually exclusive, but can be combined to strengthen the validity of findings and broaden understanding of the mathematics teaching and learning process. Qualitative research in mathematics education employs various complementary data collection techniques to obtain a deep understanding. The three main techniques employed are in-depth interviews, participatory observation, and document analysis.

Table 1. Types of Qualitative Researchs

Qualitative Approach	Focus of Study	Goals/Contributions in Mathematics Education
Ethnography	Classroom culture, values, habits, language, and social interactions that shape how students learn mathematics.	To understand the classroom culture holistically and see how social and cultural contexts influence the mathematics learning process.
Phenomenology	Students' lived experience in understanding and interpreting mathematical concepts.	To explore the essence of students' learning experiences, such as perceptions of difficulties, successes, or anxiety in mathematics.
Case Study	Specific phenomena in mathematics learning (bounded system), such as critical thinking processes in a particular group.	To provide a deep, granular understanding of learning phenomena within a real-life context, often involving multiple data sources.
Grounded Theory	Empirical data from students' mathematics learning activities to generate a general theory.	To develop new theories grounded in field data, such as a model of students' cognitive stages in understanding specific concepts.

Source : Creswell & Poth (2018), Stanley (2024), and Fraenkel et al. (2012)

By combining these three techniques, researchers can conduct triangulation to strengthen the validity of the findings and obtain a complete picture of the relationship between classroom culture and students' mathematical thinking processes.

In qualitative research, data analysis is conducted inductively and iteratively. Creswell (2018) explains that the analysis process begins with data organization, thorough reading, coding, category development, and the development of main themes. Meanwhile, Fraenkel, Wallen, & Hyun (2012) add that researchers must continuously review the data to ensure consistency and interconnectedness between themes. This iterative analysis process is also emphasized by Sukirwan, Nindiasari, Warsito, & Saleh (2023) in their study of ethnomathematics in Indonesia. In mathematics education, this process helps researchers uncover students' thinking patterns, problem-solving strategies, and how social context shapes their understanding of mathematical concepts (Rahmawati, Zaenuri, & Hidayah, 2023).

In mathematics education research, qualitative researchers employ three main data collection techniques that are not merely theoretical but grounded in fieldwork. The

following table presents these techniques along with specific examples of how they are applied in actual mathematics classroom studies:

Table 2. Data Collection Techniques in Mathematics Education Research

Data Collection Technique	Example from Mathematics Research	Research Purposes	Data Source
In-depth Interview	Asking students: "Why did you use that strategy to solve the problem?" to understand their thinking processes in PMRI-based learning	Understanding students' mathematical reasoning and problem-solving strategies not visible through observation	Students, teachers, educators
Participatory Observation	Observing how students interact in groups while solving realistic mathematics problems based on local context; noting teacher feedback and student discussions	Capturing authentic classroom dynamics and social interactions that influence mathematical understanding	Classroom activities, student-teacher interactions
Document Analysis	Analyzing student worksheets from PMRI lessons, comparing student solutions, examining learning progress through assignment submissions	Triangulating interview and observation data; identifying patterns in student thinking and conceptual development	Student worksheets (E-LKPD), assignment records, lesson plans

Source: Fraenkel et al. (2012) and Creswell & Poth (2018)

To ensure the reliability and validity of the results, the trustworthiness criteria were used as proposed by Lincoln & Guba (in Creswell, 2018), which includes four main aspects as Table 3.

Creswell (2018) emphasizes that reflexivity is an important part of confirmability, where researchers must be aware of and re-examine how their values, beliefs, and backgrounds can influence the interpretation of data.

Table 3. Trustworthiness Criteria

Trustworthiness Criteria	Purpose/Meaning	Implementation Strategy
Credibility	Ensuring that research findings represent the actual reality of the participants (internal validity).	Triangulation(methods/sources),member checking(validating with participants), andprolonged engagementin the field.
Transferability	Assessing whether findings can be applied to other contexts (external validity).	Providingthick description—rich, detailed accounts of the context so readers can determine applicability.
Dependability	Demonstrating that the findings are consistent and could be repeated (reliability).	Audit trails—detailed documentation of the entire research process, data collection, and analysis decisions.
Confirmability	Ensuring results are based on data, not researcher bias (objectivity).	Reflexivity(researcher self-reflection on bias) and cross-checking data interpretation with peers (peer debriefing).

Source: Lincoln and Guba in Creswell & Poth, 2018

The qualitative approach contributes significantly to the development of theory and practice in mathematics education, as it allows for a deeper understanding of students' mathematical thinking processes within the social and cultural contexts of the classroom (Sukirwan, Nindiasari, Warsito, & Saleh, 2023). Theoretically, qualitative research plays a role in broadening perspectives on mathematics learning theories, which were previously largely constructed through quantitative approaches. Through inductive and interpretive processes, it allows for the emergence of new theories derived directly from students' experiences in the field (Rahmawati, Zaenuri, & Hidayah, 2023). Findings such as mathematical communication patterns, student thinking strategies, and the dynamics of social interactions in the classroom can enrich understanding of how mathematical knowledge is socially and cognitively constructed, thus helping to develop a more contextual and realistic theoretical framework (Azmi, 2024).

From a methodological and practical perspective, a qualitative approach has implications for designing more contextual, reflective, and student-centered mathematics learning (Widiyasari, Astriyani, & Purwoko, 2023). Through participant observation and in-depth interviews, researchers and teachers can understand how students relate mathematical concepts to everyday life experiences, both through local cultural contexts and social activities within the school environment (Mufti, 2025a). This supports the implementation

of approaches such as Realistic Mathematics Education (RME) or Indonesian Realistic Mathematics Education (PMRI), which emphasize the connection between mathematics and the real world (Mulbasari, Putri, Zulkardi, & Aisyah, 2024). Qualitative research findings also help teachers identify students' conceptual difficulties, improve mathematical communication patterns, and design learning strategies that are more adaptive to students' differing ways of thinking (Azmi, 2024).

Furthermore, the socio-cultural implications of qualitative research serve as a fundamental catalyst for the development of inclusive and equitable mathematics education. Aligning with Creswell's (2018) assertion, the construction of mathematical meaning is inherently embedded within the student's cultural context; culture is not merely a backdrop but a primary determinant that dictates how students interact, negotiate ideas, and interpret complex mathematical abstractions.

Through ethnographic and phenomenological lenses, qualitative research enables an analytical penetration into classroom norms, value systems, and linguistic discourses to unveil how these sociocultural elements drive the cognitive dynamics of students. These findings provide a crucial empirical foundation for developing culture-sensitive curricula that respect the pluralistic identity of the Indonesian context while bridging learning gaps. Consequently, the qualitative approach transcends mere methodological enrichment; it steers the paradigm of mathematics education toward a more humanistic, reflective, and profoundly contextual framework.

Research demonstrates concrete mechanisms linking classroom culture directly to students' mathematical thinking. Ethnographic studies in Indonesian classrooms reveal that classroom norms fundamentally shape cognitive processes. For example, Sukirwan et al. (2023) documented that in classrooms where collaborative problem-solving aligns with local cultural values—such as collective decision-making in traditional communities—students develop distinctly different mathematical cognition: they verify solutions through group discussion rather than individual checking, verify answers through collective reasoning rather than relying on answer keys, and approach unfamiliar problems by drawing on communal knowledge. This is not merely cultural adaptation; it represents a fundamental restructuring of how students' minds engage with mathematical problems. Similarly, Azmi (2024) found that when classroom instruction incorporates Acehnese cultural values and ethnomathematics, students' mathematical reasoning patterns reflect culturally familiar explanation schemas. Students internalize culturally congruent ways of justifying their

mathematical solutions, demonstrating that culture is not external decoration but constitutive of cognitive structure.

The mechanisms connecting culture and cognition are specific and measurable. When classroom communication norms encourage students to explain mathematics using their own language and cultural references rather than enforcing decontextualized mathematical terminology, students develop significantly deeper conceptual understanding (Ayu, 2023; Irawan et al., 2025). When classroom activities ground mathematics in students' lived experiences—such as PMRI approaches using traditional market transactions, agricultural practices, or craft production—students' problem-solving strategies become anchored in their cultural knowledge, fundamentally altering cognitive architecture (Rahmawati et al., 2023). Students activate cognitive schemas rooted in their cultural experience rather than treating mathematics as abstract symbol manipulation. Widiyasari et al. (2023) documented through case studies that students in classrooms integrating local wisdom—such as traditional geometric patterns in textiles or architectural knowledge—develop mathematical cognition that is simultaneously rigorous and culturally grounded; they engage abstract geometric thinking while maintaining meaningful connections to cultural heritage.

These findings establish that mathematical cognition emerges from classroom culture. Through ethnographic investigation, researchers have identified that classroom culture operates through three mechanisms that directly reshape cognitive development. First, social norms establish cognitive expectations: when classroom culture emphasizes deliberation and peer verification over speed and individual performance, students internalize slow, collaborative thinking patterns (Ghamrawi et al., 2025). Second, linguistic and communicative patterns shape conceptual formation: the language classroom members use to explain, question, and validate ideas directly influences conceptual development (Mufti, 2025a). Third, cultural meaning-making frameworks structure problem-solving: when mathematics is embedded in culturally meaningful contexts, students' cognitive processing shifts from abstract symbol manipulation to situated, culturally grounded reasoning.

Therefore, the evidence shows unequivocally that classroom culture and cognitive dynamics are not separate; they are integrated aspects of mathematical learning. Classroom culture provides the framework within which cognition develops. Qualitative research methods—ethnography's capacity to uncover hidden cultural norms, phenomenology's

ability to reveal how students experience mathematical learning within cultural contexts, and case studies' granular documentation of culture-cognition mechanisms—are indispensable for understanding this relationship. By integrating these qualitative insights with pedagogical frameworks such as PMRI, educators gain evidence-based foundations for designing classroom cultures that support robust mathematical thinking rooted in students' social realities and cultural identities. This is not merely about making mathematics more culturally relevant; it is about recognizing that mathematical cognition itself is culturally constituted. Thus, qualitative research reveals that culturally responsive classroom design is essential—not as supplementary enrichment but as fundamental to how students' mathematical minds develop.

Conclusion and Suggestion

This literature review underscores that qualitative inquiry, particularly through ethnographic and case study lenses, is indispensable for unveiling the intricate relationship between classroom culture and cognitive dynamics in mathematics education. The synthesis of research from the last decade (2015–2025) demonstrates that mathematical thinking is not an isolated mental exercise but is a process deeply embedded within social interactions, linguistic norms, and cultural values. Ethnography serves as a powerful tool to deconstruct the "hidden curriculum" and socio-mathematical norms that dictate how students negotiate meaning, while case studies offer a granular examination of the specific cognitive hurdles encountered during this process. Furthermore, the integration of these qualitative insights with constructivist frameworks like Pendidikan Matematika Realistik Indonesia (PMRI) provides a robust pathway to bridge the gap between abstract mathematical concepts and the pluralistic social realities of Indonesian students. Ultimately, by prioritizing humanistic and contextual paradigms, qualitative research ensures that mathematical understanding is seen as a socially constructed journey rather than mere rote memorization.

Based on these findings, the following recommendations are proposed to advance both research and practice:

For Future Research: Scholars are encouraged to move beyond fragmentary studies by adopting integrated research designs that simultaneously analyze students' cognitive shifts alongside the evolving culture of the classroom. There is a specific need for longitudinal ethnographic studies to track how long-term exposure to culturally responsive environments shapes a student's mathematical identity.

For Educators and Practitioners: Professional development should focus on enhancing "teacher noticing" skills, enabling educators to interpret students' informal thinking and leverage local cultural contexts as cognitive scaffolds.

For Policymakers: Curriculum development must explicitly integrate local wisdom and socio-cultural values to foster a more inclusive and equitable learning environment that resonates with the diverse Indonesian context.

This literature review highlights the critical role of qualitative research, particularly ethnography and case study approaches, in bridging the gap between individual cognition and social context in mathematics education. The synthesis of recent studies (2015–2025) demonstrates that students' mathematical thinking is not an isolated cognitive event but is deeply embedded in the classroom culture, social interactions, and linguistic norms. Ethnography effectively unveils the "hidden curriculum" and cultural values that shape learning, while case studies provide granular insights into the specific cognitive hurdles and strategies students employ.

The integration of these approaches offers a robust framework for understanding how constructivist and contextual learning models, such as Pendidikan Matematika Realistik Indonesia (PMRI), function in practice. By prioritizing meaning-making over rote memorization, qualitative inquiry validates that mathematical understanding is socially constructed. Furthermore, the rigorous application of trustworthiness criteria—credibility, transferability, dependability, and confirmability—ensures that these qualitative insights are scientifically valid and reliable, offering a complementary perspective to quantitative measurements of student achievement.

Based on the findings, several recommendations are proposed for future research and educational practice. First, researchers are encouraged to conduct more longitudinal ethnographic studies to track the evolution of classroom culture and its long-term impact on students' mathematical identity. Second, there is a need for more integrated research designs that simultaneously examine teacher pedagogical beliefs and student cognitive outcomes using mixed-method approaches to provide a more holistic picture.

For practitioners and policymakers, it is suggested that teacher professional development programs should include training on "teacher noticing" and qualitative assessment techniques. Educators should be equipped with the skills to observe and interpret students' informal mathematical thinking and cultural backgrounds, enabling them to design more inclusive and culturally responsive learning environments. Finally, curriculum

developers should explicitly incorporate local cultural contexts into mathematics materials to foster greater student engagement and conceptual understanding.

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