Uncovering Ethnomathematical Potentials in Local Culture for the Development of a Mathematics Learning Model that Promotes Critical Thinking

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Article Info

ISSN (Online): 2582-7138
Impact Factor (RSIF): 8.04
Volume: 07
Issue: 03
Received: 26-04-2026
Accepted: 28-05-2026
Published: 30-06-2026
Page No: 1187-1192

Abstract
This study aims to analyze the needs for developing a mathematics learning model that integrates local culture and deep learning to enhance students' critical thinking skills. The research employed a descriptive qualitative approach involving mathematics teachers and junior high school students in East Nusa Tenggara. Data were collected through questionnaires, interviews, and observations, focusing on teachers' perceptions, classroom practices, and students' learning needs related to local cultural contexts. The results indicate that current mathematics learning practices are still dominated by procedural understanding, with limited integration of local cultural contexts and deep learning principles. Teachers expressed the need for a contextual model that connects mathematical concepts with local traditions, values, and problem-solving processes relevant to students' daily lives. The study concludes that integrating local culture with deep learning principles has the potential to transform mathematics learning into a more meaningful and reflective process that fosters students' critical thinking.

DOI: https://doi.org/10.54660/.IJMRGE.2026.7.3.1187-1192

Keywords: critical thinking, deep learning, ethnomathematics, local culture, mathematics education

1. Introduction

The rapid development of artificial intelligence technology presents both significant challenges and opportunities for mathematics learning [1]. On the one hand, artificial intelligence offers adaptive learning systems, intelligent tutors, and automated learning analytics that can enrich students' learning experiences [2, 3]. However, on the other hand, reliance on this technology risks undermining critical thinking skills if students simply accept results without understanding the mathematical thought processes behind them. Therefore, innovative learning models are needed that can instill reflective awareness so that students can use technolog critically and responsibly. One potential strategy is to develop a local culture-based learning model that utilizes a deep learning framework to foster critical thinking skills. This approach enables students to see the connections between mathematics, everyday life, and their culture, making learning more meaningful and contextual [4, 5]

Given the relevance and effectiveness of contextual, locally based learning, also known as Ethno-RME, a thorough needs analysis is crucial before developing a learning model that integrates cultural wisdom and deep learning strategies [6, 7]. This needs analysis helps identify gaps between the formal curriculum and students' cultural realities, as well as uncover potential conceptual barriers when students encounter abstract mathematical ideas without the support of cultural context. Previous research has shown that ethnomathematics-based learning can enhance students' engagement and conceptual understanding by bridging everyday experiences with formal mathematical ideas [8,9]. Furthermore, a Realistic Mathematics Education (RME) approach adapted to a local cultural context can strengthen students' critical thinking and mathematical problem-solving skills, especially when combined with deep learning principles such as reflection, inter-concept connections, and meaning construction [10–12].

Therefore, before widespread implementation, a needs analysis is essential to ensure that the local culture-based learning model supported by in-depth learning truly suits the students' characteristics and socio-cultural context, so that it can shape a generation that thinks critically and wisely in utilizing AI in mathematics learning. Previous studies have shown that integrating local culture into mathematics learning, such as through the Ethnomathematics or Ethno-Realistic Mathematics Education (Ethno-RME) approach, consistently improves students' conceptual understanding, mathematical connections, and critical thinking skills [13–15]. Ethnomathematics not only enriches the learning experience but also encourages in-depth reflection on the meaning of mathematics within a cultural context, which serves as the foundation for deep learning. The RME approach adapted to the local Indonesian cultural context significantly develops reflective thinking and mathematical problem-solving skills. Furthermore, deep learning strategies within the RME context enhance students' critical thinking skills through the exploration, elaboration, and evaluation of mathematical concepts [16, 17]. Overall, these findings indicate that developing a local culture-based mathematics learning model combined with the principles of deep learning is an effective strategy for forming a generation of students who are critical, reflective, and adaptive to changing times.

Although various previous studies have demonstrated the effectiveness of integrating local culture into mathematics learning and the relevance of the Realistic Mathematics Education approach to improving critical thinking skills, significant gaps remain that need to be addressed in the context of actual implementation. Most previous studies have focused on the application of the RME or ethnomathematics model in isolation without integrating the principles of deep learning pedagogy, which emphasizes reflection, exploration, and continuous construction of meaning [18,19]. Furthermore, these studies generally have not explicitly examined how culture-based learning can serve as a bridge to developing students' critical thinking skills. Another limitation is the lack of a systematic need's analysis of teachers, students, and the local cultural context to ensure the suitability of the learning model to be developed. Thus, this research is important to be conducted to fill this gap through a comprehensive needs analysis as a basis for developing a local culture-based mathematics learning model with in-depth learning support to strengthen students' critical thinking skills in the digital era.

The novelty of this research lies in the integration of three main dimensions that have not been explored simultaneously in previous studies: [1] local cultural context, [2] implementation of deep learning principles, and [3] orientation towards strengthening students' critical thinking skills. Unlike previous studies that emphasized the effectiveness of ethnomathematics or RME separately, this research focuses on the need's analysis stage as a conceptual basis for designing a learning model that is contextual, reflective, and adaptive to technological developments. By combining local NTT culture as a learning context, deep learning as a pedagogical strategy, and critical thinking skills as an expected outcome, this research presents a new conceptual model that is not only relevant to local realities but also aligned with the direction of transformation of 21st-century mathematics education.

2. Method

2.1. Research Design

This study employed a qualitative descriptive design, deemed appropriate for gaining a deep understanding of the needs of teachers and students in developing a locally based mathematics learning model using an immersive learning approach to enhance students' critical thinking skills. This design was chosen because it allowed researchers to explore and describe phenomena naturally as they occur in the school context, resulting in rich and contextual data about ongoing learning practices, challenges faced, and expectations for mathematics learning integrated with local culture.

2.2. Data Collection

The research procedure involved several stages. First, a preliminary study was conducted through a review of relevant literature to identify key concepts related to Realistic Mathematics Education, local culture, in-depth learning, and critical thinking. Second, field observations and interviews were conducted to explore the actual conditions of mathematics learning in schools and the extent to which local culture has been integrated into classroom learning practices. Third, a needs analysis was conducted by collecting data from teachers and students to identify important components and strategies that need to be included in the development of future learning models.

The population of this study consisted of mathematics teachers and school students in Kupang City, East Nusa Tenggara. The sample was selected purposively, involving 10 schools to capture a diversity of cultural and educational contexts. Participants included mathematics teachers with at least three years of teaching experience and students in grades 7 through 9.

The research instruments consisted of observation sheets, interview guides, and questionnaires. The observation sheets were used to record mathematics learning practices and interactions in the classroom. The interview guides were used to obtain in-depth information from teachers and students regarding their experiences, challenges, and perceptions of culture-based mathematics learning. Meanwhile, the questionnaires were used to collect data on the needs, expectations, and readiness of teachers and students for the development of the proposed learning model.

2.3. Data Analysis

Data were collected through classroom observations, semi-structured interviews, and questionnaires, with data triangulation applied to enhance the validity of the findings. The collected data were then analyzed using Miles and Huberman's interactive model, which includes three stages: data reduction, data presentation, and conclusion drawing or verification. Through this process, key patterns and themes were identified to determine the essential elements needed to develop a mathematics learning model that integrates local culture and in-depth learning to foster students' critical thinking skills.

3. Results and Discussion

3.1. Results

3.1.1. Class observation results

This section presents the results of classroom observations conducted as part of the needs analysis for developing a

culturally based mathematics learning model integrated with a deep learning approach. The observation aimed to identify the actual conditions of teaching and learning processes, student engagement, the use of local cultural contexts, and the extent to which current instructional practices have supported the development of students' critical thinking skills.

Table 1: Class observation results

No	Observed Aspects	Indicators	Field Notes
1	Planning and implementing learning	- Students clearly understand the learning objectives. - The material is linked to the context of students' daily lives. - The approach used encourages active and meaningful learning.	Students understand the learning objectives in general, the material is still abstract, teacher-centered learning approach
2	Local cultural integration (ethno-rme)	- Examples or problems stemming from local culture (traditional measuring instruments, market activities, customs, etc.) are included. - Discussions foster a sense of pride in local culture. - Students can relate mathematical concepts to their local cultural activities.	The problems used are in the context of students' lives but do not originate from local culture.
3	Deep learning activities	- Students actively ask questions and further explore mathematical concepts. - Students actively engage in learning reflection. - Learning activities require collaboration, analysis, and open-ended problem-solving.	Students are guided to actively ask questions, but the response from students is still minimal.
4	Students' critical thinking abilities	- Students are able to identify problems and interpret information accurately. - Students provide logical reasons or arguments to support their answers. - Students are able to evaluate and draw conclusions based on evidence.	Students can identify problems but cannot provide logical reasons to support their answers.
5	Teacher and student interaction	- Communication is two-way and everyone's opinion is respected. - Students demonstrate confidence in expressing their ideas. - Students receive constructive feedback.	Communication is mostly one-way; most students have not shown self-confidence
6	Learning environment and student motivation	- Students appeared enthusiastic and focused during the lesson. - The learning environment was conducive and inclusive. - Learning activities fostered students' curiosity.	School facilities are still limited, with limited media and contextual teaching materials. Students are less focused on learning activities.

3.1.2. Teacher and students's interview results

This section presents the results of in-depth interviews conducted with teachers and students who participated in the study. The interviews aimed to obtain a more comprehensive understanding of the needs and challenges in mathematics learning, particularly regarding the integration of local cultural contexts and the development of students' critical thinking skills through a deep learning approach. Teachers were asked to share their experiences in designing and implementing lessons, as well as their perspectives on incorporating local cultural elements into mathematics instruction. Meanwhile, students were interviewed to explore their perceptions of classroom learning, the difficulties they encountered, and their expectations for more meaningful and contextually relevant learning experiences.

The findings from these interviews serve as an essential qualitative data source that complements classroom observations. They provide a deeper insight into the reality of mathematics learning in schools and form the basis for designing a culturally based mathematics learning model integrated with deep learning principles to enhance students' critical thinking skills.

Table 2: Results of interviews with teachers and students

Main Theme	Findings from teachers	Findings from students
Understanding of RME	Teachers have limited knowledge of RME; understanding RME is limited to contextual learning.	Students rarely experience learning that uses the real context of their area.
Local culture-based learning	Teachers consider local culture difficult to integrate into mathematics materials	Students are enthusiastic if learning involves students actively and is linked to activities that students often encounter, such as cultural activities of buying and selling at the market, making traditional cakes, and making woven cloth.
Students' critical thinking abilities	Teachers realize that students have difficulty analyzing and evaluating mathematical solutions.	Students admit that they memorize formulas more often than they understand concepts.
Expectation for learning	Teachers hope that there will be models that are easy to implement and relevant to the local cultural context.	Students want learning that is more interesting and not just filled with formulas.

3.1.3. Teacher Questionnaire results

This section presents the results of questionnaires completed by mathematics teachers who participated as respondents in the study. The questionnaire was designed to identify teachers' needs, perceptions, and readiness in implementing a culturally based mathematics learning model integrated with a deep learning approach. Through this instrument, data were obtained on teachers' understanding of critical thinking concepts, the extent to which they have incorporated local cultural values into their teaching practices, and the challenges they face in fostering meaningful and reflective learning experiences.

The data from the teacher questionnaire provide a quantitative overview that complements the findings from classroom observations and interviews. This combination allows for a more objective mapping of the needs related to developing a learning model suited to the context of schools and student characteristics in East Nusa Tenggara (NTT) especially Kota Kupang. The results also form the foundation for designing a more adaptive learning intervention aimed at enhancing students' critical thinking skills through the integration of local cultural contexts in mathematics education

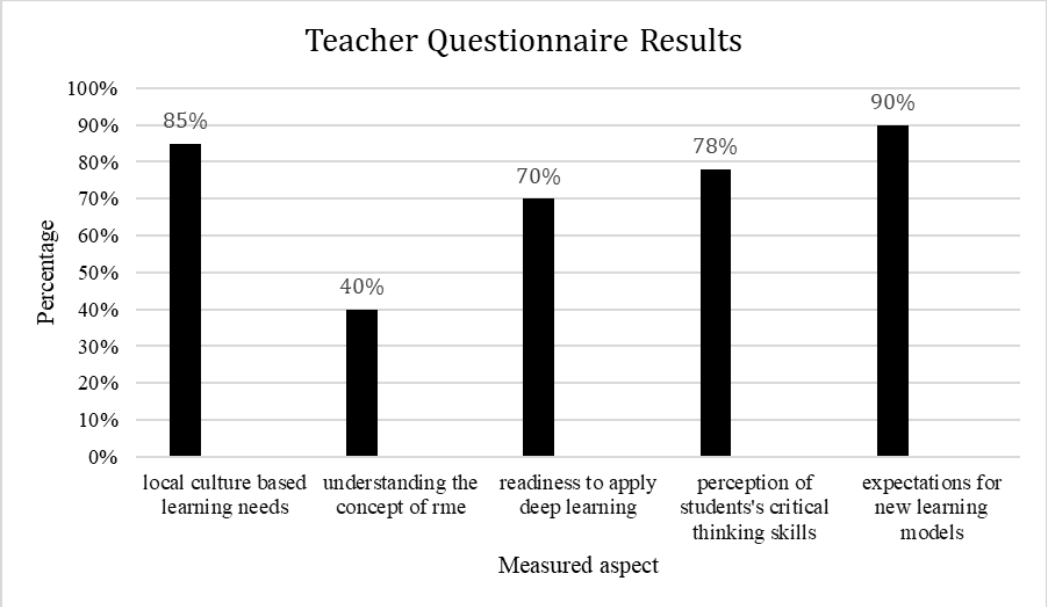

Fig 1: Teacher Questionnaire Results

3.2. Discussion

The results of this study indicate that mathematics instruction in several schools in Kupang remains conventional and has not fully developed students' critical thinking skills. This condition directly addresses the research objective, which aimed to analyze the need to develop a local culture-based mathematics instructional model using in-depth learning. Scientifically, this finding can be interpreted as reflecting a gap between the 21st-century learning paradigm, which emphasizes critical thinking skills, and learning practices in the field, which still focus on procedural outcomes. This is in line with findings showing that mathematics teachers in Indonesia still experience difficulties in implementing learning that fosters critical thinking due to limited understanding of cultural contexts and reflective learning strategies [20–22]

Furthermore, interview and questionnaire results show that teachers and students exhibit high enthusiasm for learning linked to local culture. This fact reinforces the ethnomathematics theory that mathematics should be understood as a product of culture and social practices inherent in community life. Thus, a local culture-based learning model approach combined with deep learning has strong relevance in the educational context of NTT. Previous research, such as that integrating local culture and RME, has demonstrated effectiveness in improving conceptual understanding but this study offers novelty by incorporating aspects of deep learning pedagogy as a bridge to hone student reflection, collaboration, and critical analysis, something less discussed in previous literature.

From a theoretical perspective, the results of this study broaden the understanding that the local cultural context is not only a means to facilitate mathematics learning but can also be a forum for internalizing values, understanding concepts, and developing critical thinking patterns. This supports the social constructivism perspective, which emphasizes the role of the social and cultural environment in shaping individual thought processes [23]. However, the results of this study also show a difference from several findings that state that local cultural integration has not had a significant effect on critical thinking skills, because in the context of this study, the local culture of NTT has proven to be very potential and contextually relevant to basic mathematical concepts.

The practical implications of this research are the need to develop a local culture-based learning model with in-depth learning equipped with contextual teaching tools, teacher training, and student reflection guides to improve the quality of critical thinking processes. Furthermore, these results open up broader future research directions, such as the development of a prototype learning model in the form of a module, limited trials to determine its effectiveness on student learning outcomes and attitudes, and cross-cultural research in other regions in Indonesia.

4. Conclusion

Based on observations, in-depth interviews, and questionnaires, this study concludes that mathematics learning in several schools in Kupang, East Nusa Tenggara, Indonesia is still dominated by conventional approaches that emphasize procedural solutions and do not fully encourage students' critical thinking skills. Teachers and students demonstrate a strong need for learning models that are contextual, relevant to local culture, and capable of activating deep cognitive engagement. This needs analysis confirms that developing a local culture-based mathematics learning model with a deep learning approach is crucial to address the challenges of mathematics education. The proposed model, Ethno-Realistic Mathematics Education (Ethno-RME) based on deep learning, is expected to bridge students' conceptual understanding through local cultural exploration, as well as foster critical, reflective, and creative thinking skills. Practically, these findings provide an important basis for the development stage of learning models in subsequent research (the Design phase in the 4D model), including the development of local culture-based teaching materials and teacher training in implementing deep learning strategies. The implications of this study also open opportunities for further research evaluating the effectiveness of the developed model in improving students' critical thinking skills, conceptual understanding, and character in different cultural contexts in Indonesia.

6. Thank-You Note

The researcher would like to express heartfelt gratitude to Universitas Muhammadiyah Kupang for the support, facilities, and opportunities provided throughout the implementation of this study. Sincere appreciation is also extended to Universitas Muhammadiyah Malang, especially to the academic supervisors and colleagues, for their invaluable guidance, scholarly input, and constructive feedback during the preparation and completion of this research

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How to Cite This Article
Fatmawati A, Utomo DP, Purwanti E, Baiduri. Uncovering ethnomathematical potentials in local culture for the development of a mathematics learning model that promotes critical thinking. International Journal of Multidisciplinary Research and Growth Evaluation. 2026;7(3):1187-1192. doi:10.54660/IJMRGE.2026.7.3.1187-1192.