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The Effectiveness of Realistic Mathematics Learning Based on Mandailing Culture with a Deep Learning Approach In Improving Logical Thinking Skills

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***Abstract*:**
The purpose of this study was to develop and test the effectiveness of a Realistic Mathematics learning model based on Mandailing culture with a Deep - Learning approach in improving the logical thinking skills of high school students. This approach aims to build a deep and meaningful understanding of concepts through the integration of local cultural contexts that are close to students' lives. The methodology used is the development research method with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The analysis stage involves literature studies and field observations to identify students' needs and relevant Mandailing cultural potential. The design and development stage produces learning tools in the form of lesson plans, student worksheets, and learning media that have been validated by material experts and cultural experts. Implementation was carried out through a quasi-experiment in two classes (experimental and control) with a logical thinking test instrument as the main measuring tool. Evaluation was carried out formatively and summatively to determine the effectiveness of learning. The results showed that students who participated in Realistic Mathematics learning based on Mandailing culture with a Deep Learning approach experienced a significant increase in logical thinking skills compared to the control group. In addition, students showed enthusiasm and active involvement because the learning was linked to the culture they were familiar with. The conclusion of this study is that mathematics learning that integrates local culture with an immersive learning approach is effective in improving students' logical thinking skills. This model also strengthens cultural identity while developing higher-order thinking skills. Recommendations are directed to teachers, curriculum developers, and educational policymakers to consider a contextual learning approach based on local culture as a strategy to improve the quality of learning processes and outcomes, particularly in developing students' logical and cognitive thinking skills.

Keywords: Logical Thinking, Mandailing Culture, Deep Learning, Realistic Mathematics, ADDIE Model

Introduction

Ideally, mathematics learning should not only emphasize mastery of algorithms and procedures but also be directed toward developing higher-order thinking skills, particularly logical thinking. Logical thinking is the foundation for understanding mathematical concepts in depth, drawing valid conclusions, and solving complex problems coherently and systematically (Krulik & Rudnick, 1999). This ability is crucial for developing the critical and reflective thinking patterns required for 21st-century learning (OECD, 2019). Furthermore, recent research confirms that active student engagement through learning strategies that emphasize analysis, evaluation, and synthesis of the key components of Higher-Order Thinking Skills (HOTS) significantly contributes to improved logical thinking skills (Gradini et al., 2025). In mathematics classrooms, the application of Inquiry-Based Learning and Collaborative Learning approaches has been shown to strengthen conceptual analysis and authentic problem solving (Gradini et al., 2025; Triwidayati et al., 2024).

However, the reality on the ground shows that mathematics learning in schools, particularly in rural areas, remains conventional, teacher-centered, and outcome-oriented, leaving no room for logical exploration and conceptual understanding. Students tend to memorize formulas and procedures without understanding their conceptual meaning. As a result, they have difficulty applying mathematical concepts in real-world situations and demonstrate weaknesses in logical thinking (Susanto, 2021; Utami & Mulyani, 2020). This situation is exacerbated by studies in several regions in Indonesia that reveal that mathematics textbooks and teacher teaching practices rarely include real-world context-based tasks, leaving students with only procedural instructions without meaningful problem-solving transformation processes (Wijaya et al., 2014). Researchers Wijaya et al. (2015) stated that only around 10% of problems in Indonesian mathematics textbooks are contextual, and teachers often use a directive approach that limits students' opportunities for critical and creative thinking. This imbalance indicates the need for a more contextual and meaningful learning approach for students.

One relevant approach to addressing these challenges is Realistic Mathematics Education (RME), developed by Freudenthal and Gravemeijer. RME emphasizes the use of real-world contexts close to students' lives as a starting point for gradually building an understanding of mathematical concepts (Gravemeijer, 1994). A recent meta-analysis conducted by Nurintya et al. (2024) showed that the implementation of RME significantly improved students' critical thinking and problem-solving skills, with an effect size of approximately 2.90, a very large category compared to traditional expository learning. Furthermore, a study by Gunawan and Hadi (2024) demonstrated that RME is effective in improving students' conceptual and procedural understanding, especially for students with diverse initial reasoning abilities. This approach can be strengthened by integrating local cultural values and contexts, as revealed by Gay (2010), who argued that culture-based learning not only strengthens

students' identities but also increases their engagement and understanding. Ethno-RME practices that have been developed in various regions in Indonesia, such as modules based on Sundanese culture or Pancasila values, have been proven valid and effective in improving students' critical reasoning skills and mathematical literacy (Pujiastuti et al., 2024; Imswatama & Saepuloh, 2024).

Furthermore, 21st-century learning demands deep learning, a learning process that emphasizes in-depth understanding, reflection, connections between concepts, and the transfer of knowledge to new situations (Fullan et al., 2018). Combining RME with deep learning strategies such as reflective discussions, contextual problem-solving, and the use of concept maps has been shown to expand students' higher-order thinking skills, including logical, critical, and reflective thinking (Fullan et al., 2018). Therefore, the integration of RME, local cultural context, and deep learning approaches is not only relevant but also crucial as an effective contextual pedagogical solution.

Although RME has been widely applied in various educational contexts, there has been little research developing a realistic mathematics learning model based on specific local cultures, such as Mandailing culture. This is despite the fact that Mandailing culture possesses a wealth of values, pattern structures, and social contexts that can be used as contextual teaching materials in mathematics learning. This aligns with findings in a systematic review of ethnomathematics in Sundanese culture, which showed that integrating local cultural contexts, such as traditional patterns and community symbols, significantly improves students' conceptual understanding and mathematical abilities (Supriyadi et al., 2022). Furthermore, an analysis of ethnomathematics research trends in Indonesia shows that, despite growing interest in cultural integration, research focused on Mandailing culture and the use of deep learning approaches remains minimal (Rusli & Safaah, 2023). Yet, integrating local culture into RME has the potential to simultaneously increase the relevance of learning and build students' cultural identity. Furthermore, the deep learning approach has not been widely combined with RME and local cultural integration, particularly to comprehensively improve students' logical thinking skills. The combination of RME, local culture, and deep learning is called a promising innovative strategy by researchers, because it is able to address the cognitive, affective, and identity aspects of students simultaneously (ethnomathematics as contextual learning) (Nur et al., 2023).

This research offers novel value in the development of a realistic mathematics learning model integrated with Mandailing culture through a deep learning approach. This model is expected to create a learning process that is not only effective in improving students' logical thinking skills but also contextually relevant and culturally meaningful. In addition to potentially increasing mathematical reasoning efficacy, the integration of Mandailing culture can strengthen students' local identity and emotional connection to the lesson, as evidenced by a systematic analysis of

ethnomathematics in Sundanese culture that showed positive effects on mathematical understanding and student engagement (Supriyadi et al., 2022). Furthermore, a meta-analysis of digital ethnomathematics in Indonesia revealed that the use of local cultural contexts in digital learning platforms significantly improved students' conceptual understanding and critical mathematical thinking skills, with effect sizes ranging from medium to high (Mauladaniyati et al., 2024). In this context, the combination of RME, local culture, and deep learning emerges as an innovative and transformative pedagogical strategy. encourage students to think deeply, reflectively, and contextually and simultaneously preserve Mandailing cultural values. Thus, this research not only addresses current pedagogical issues but also contributes to the preservation of local culture through transformative and sustainable educational innovation.

Research Methods

This study used a quantitative approach with a quasi-experimental design, as it aimed to measure the effectiveness of the developed learning model without class randomization. The design used was a nonequivalent control group design, in which two groups (experimental and control) were compared through a pretest and posttest (Creswell & Creswell, 2018). This approach is commonly used in educational intervention studies involving model development, as it allows for analysis of the treatment's impact on measurable variables such as logical thinking skills (Setiawan et al., 2021, Journal of Physics: Conference Series).

The subjects were eighth-grade students from a junior high school in Mandailing Natal Regency, selected purposively based on similarities in academic and environmental characteristics. The experimental class received realistic mathematics instruction based on Mandailing culture using a deep learning approach, while the control class used conventional learning. The object of the study was students' logical thinking skills, which are indicators of the success of the learning model implementation.

Logical thinking ability test, developed based on logical thinking indicators such as deduction, induction, analogy, and inference (Krulik & Rudnick, 1999), and adapted to local mathematical and cultural contexts. Observation sheets are used to monitor the implementation of learning and student involvement during the learning process. Student response questionnaire, used to assess students' perceptions of culture-based learning and deep learning. An open-ended interview guide was used to elicit in-depth responses from teachers and students as complementary qualitative data (Suwandi et al., 2023, International Journal of Instruction). The research procedure follows the stages of the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model which has been widely used in studies of context-based and technology-based learning development (Branch, 2009; Altun & Yücel-Toy, 2020, Education and Information Technologies).

In the Analysis stage, an analysis of student needs, difficulties in logical thinking, and exploration of Mandailing cultural elements that are relevant to mathematics learning is carried out. At the Design stage, learning tools (RPP, LKPD, interactive media) are prepared that integrate local culture and deep learning approaches such as modeling, in-depth reflection, and concept elaboration. The Development stage includes the creation of learning products and validation by material experts and cultural experts. The Implementation stage involves carrying out learning in the experimental class for 4–6 meetings, as well as collecting pretest and posttest data. The evaluation stage is carried out formatively (during learning) and summatively (at the end of learning) to assess the effectiveness of the model. The data collected in this study consisted of : (1) quantitative data, namely pretest and posttest scores of students' logical thinking skills , (2) qualitative data, in the form of observation results, questionnaires and interviews.

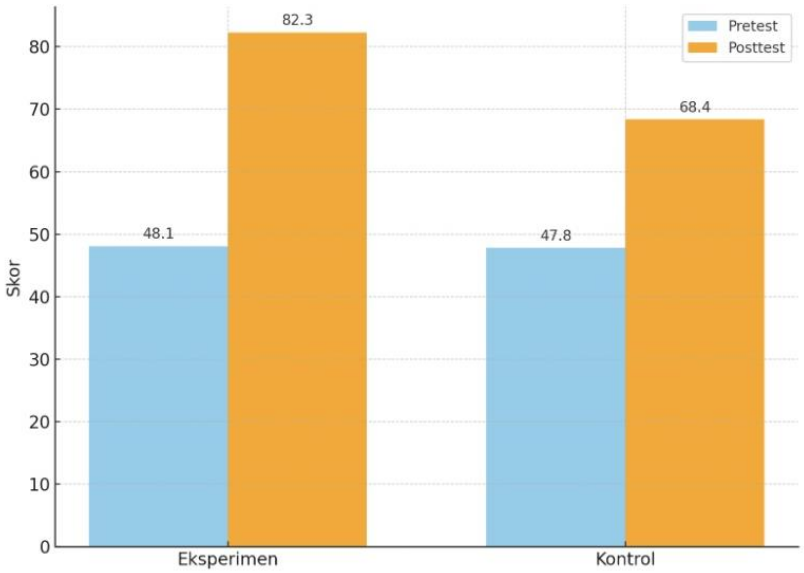
Data collection was conducted directly through pre- and post-treatment tests, observations during the learning process, and questionnaires and interviews after the learning process. Data collection adhered to ethical standards for educational research, including school approval and the active, voluntary involvement of participants. The data analyzed included: (1) students' pretest and posttest scores to assess the improvement of logical thinking skills, (2) observation and questionnaire data, to see students' involvement and their perceptions, (3) interview results, to strengthen the quantitative findings and explore the contextual dimensions of learning , (4) a quantitative data analysis was conducted using parametric statistical tests, namely the independent samples t-test to compare the average scores between groups and the N-Gain test to see the relative effectiveness of learning (Hake, 1998). The analysis was conducted using statistical software such as SPSS. Qualitative data analysis uses a thematic descriptive approach through the stages of data reduction, data presentation, and drawing conclusions (Miles et al., 2014), in order to explore students' learning experiences in culture-based learning and deep learning approaches.

Results and Discussions

This study aims to test the effectiveness of realistic mathematics learning based on Mandailing culture combined with a deep learning approach in improving students' logical thinking skills. Results were obtained through a series of pretests and posttests on two groups: an experimental group and a control group. The experimental group was given a learning model based on local culture and deep learning, while the control group used a conventional approach.

Table 1. Average Pretest and Posttest Scores of Logical Thinking Ability

Group	Pretest (Mean)	Posttest (Mean)	Difference	N-Gain	Effectiveness Category
Experiment	48.10	82.30	34.20	0.70	Tall
Control	47.80	68.40	20.60	0.39	Currently



Picture 1. Bar diagram comparing pretest and posttest scores

The bar graph above shows that the experimental group experienced a significant increase in posttest scores compared to the control group. This indicates that the applied learning model was more effective in improving students' logical thinking skills. The tables and graphs presented show a striking difference between the experimental and control groups. The experimental group experienced a score increase of 34.20 points, with a Normalized Gain (N-Gain) value of 0.70, which is included in the "high" category according to Hake's (1998) classification. Meanwhile, the control group only experienced an increase of 20.60 points with an N-Gain of 0.39 (the "moderate" category).

This finding aligns with a study by Putri et al. (2023), which found that Realistic Mathematics Education (RME) is highly effective in improving students' literacy and higher-order thinking skills due to its contextual and meaningful nature. This research reinforces the argument that learning that integrates local culture can accelerate students' meaning-making process (Zulkardi & Putri, 2019).

Integrating Mandailing culture into mathematics learning allows students to understand abstract concepts through concrete experiences. For example, students are challenged to solve math problems based on ulos cloth patterns, local coffee plantation systems, and traditional calculations at Mandailing weddings. According to

D'Ambrosio (2001), ethnomathematics strengthens the relevance of learning and builds cultural identity through mathematics. This is supported by a study by Rosa & Orey (2016), which emphasized that a cultural approach helps students build logic through familiar and grounded experiences. Deep learning encourages students to go beyond memorizing mathematical procedures to understanding concepts, analyzing problems, and evaluating solutions. In this research, the deep learning approach was implemented through reflection activities, group discussions, concept maps, and realistic problem-solving assignments. Research by Fullan et al. (2018) shows that the deep learning approach is highly effective in developing higher-order thinking skills, including logical, reflective, and critical thinking. The improvements achieved by students in the experimental group indicate that deep learning not only fosters conceptual understanding but also helps them transfer learning to real-life situations.

Classroom Observation: There was an increase in active student participation in the experimental class. Students asked more questions, responded to their peers' opinions, and used analytical thinking to solve contextual problems. Student Survey: 85% of students stated that learning was more engaging because it used a context they were familiar with. They felt more confident and enjoyed learning mathematics. Teacher and Student Interviews: Teachers stated that cultural integration made it easier for students to understand the material. Students said that "learning math feels like telling stories about our own lives." These data strengthen the argument that a contextual and immersive approach significantly improves students' engagement and quality of logical thinking. The results of this study align with a study by Widodo & Sari (2023), which found that contextual learning with a local cultural approach significantly improves students' thinking processes in basic mathematics. Similarly, Suryadi (2022) found that students will think logically if given the space to solve problems in their own context, rather than simply following standard formulas. Furthermore, according to Hadi & Novikasari (2022), the deep learning approach improves academic achievement and the reflective aspect of mathematics learning, particularly in logical-mathematical skills. This research shows that when the RME and deep learning approaches are combined, the effects are synergistic.

The implications that emerge from the results of this study include several aspects, including; (1) curriculum implications, there needs to be an educational policy that encourages the development of local culture-based teaching materials that support deep learning, (2) pedagogical implications , teachers need to be trained to design contextual learning that combines cultural aspects and reflective approaches , (3) evaluation implications , assessment of logical thinking skills needs to be carried out in a formative, context-based manner, and encourages reasoning, not just numerical final results. Some limitations in this research include , (1) it was conducted only in one school with a geographical scope of Mandailing culture. Further studies need to include other cultural contexts in Indonesia , (2) the duration of the research was limited (6 weeks). A more holistic research study is needed to observe the

development of logical thinking in the long term. Logical thinking assessments are still predominantly quantitative. Qualitative assessment instruments such as problem-solving rubrics or portfolios are needed.

In general, realistic mathematics learning based on Mandailing culture combined with a deep learning approach has been proven to : (1) significantly improve logical thinking skills (N-Gain = 0.70) , (2) provide meaningful and contextual learning , (3) bring mathematics closer to the reality of students' lives , (4) increase students' motivation, involvement, and self-confidence in learning mathematics. These results provide a new contribution to the field of Indonesian mathematics education, namely that pedagogical innovation based on local culture can be an effective strategy for strengthening logical thinking that is contextual, fun, and meaningful.

Conclusions and Suggestions

Based on the results of the quantitative and qualitative analysis obtained, it can be concluded that the realistic mathematics learning model based on Mandailing culture combined with a deep learning approach significantly improves students' logical thinking skills. The increase in the posttest score of the experimental group (N-Gain = 0.70, high category) compared to the control group (N-Gain = 0.39, medium category) indicates that this learning model is not only statistically effective, but also meaningful in the context of students' daily learning. The integration of local culture has been shown to provide a contextual and familiar learning experience, thus facilitating the construction of meaning and understanding of abstract mathematical concepts. Activities based on Mandailing cultural realities, such as ulos patterns, customary systems, and daily life practices, make learning feel relevant and down-to-earth. In addition, the application of a deep learning approach through reflection, in-depth discussions, and contextual problem-solving has been shown to develop higher-order thinking skills, including analysis, evaluation, and self-reflection in students. These findings are also supported by classroom observations, student questionnaires, and teacher interviews, which consistently show an increase in students' active participation, learning motivation, and self-confidence in learning mathematics. Therefore, a pedagogical approach that combines Realistic Mathematics Education (RME) and deep learning based on local culture not only improves cognitive learning outcomes but also strengthens the affective and social aspects of the learning process. This research makes an important contribution to educational innovation in Indonesia, particularly in efforts to decolonize the curriculum and strengthen cultural identity through contextual and reflective learning. Going forward, the development of similar models needs to be expanded to other cultural contexts in Indonesia to create a more inclusive, relevant, and meaningful mathematics education nationally.

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