Development of Local Culture-Based RME (South Tapanuli) for Enhancing Students' Critical Thinking Skills

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Abstract This study aims to develop a learning module based on Realistic Mathematics Education (RME) that integrates the local culture of South Tapanuli to improve students' critical thinking skills. This module is designed using the ADDIE model which includes five stages: analysis, design, development, implementation, and evaluation. Expert validation shows the module has an excellent level of feasibility with an average score of 4.6 out of a scale of 5. The implementation of the module in grade VIII students resulted in a significant improvement in learning outcomes, with the average student score increasing from 73.1 to 89.37, reflecting an increase of 22.25%. This module is effective in developing students' critical thinking skills through four main indicators: analysis, evaluation, inference, and problem-solving. The integration of the GeoGebra application in the module facilitates the visualization of abstract mathematical concepts, making learning more engaging, interactive, and contextual. Obstacles such as students' lack of understanding of certain cultural elements and limited learning time are overcome with initial cultural introduction and schedule adjustments. The results of the study show that this module is relevant, effective, and worthy of widespread application. In addition to supporting mathematics learning, this module also strengthens students' appreciation of local cultural values, making it a meaningful and contextual educational innovation.

Keywords*:* Realistic Mathematics Education, South Tapanuli Local Culture, critical thinking, ADDIE model.

Introduction

Critical thinking skills are one of the core skills that are indispensable to face increasingly complex global challenges. These skills enable individuals to analyze information in depth, make strong logic-based decisions, and solve problems in innovative and effective ways (Noreen C Facione 2013). (Sachdeva & Eggen, 2021) defines critical thinking as a set of skills that include problem identification, hypothesis formulation, data collection and analysis, and drawing conclusions based on evidence. Dias-Oliveira et al. 2024 adding that this ability includes purposeful, self-regulatory judgment to produce in-depth interpretation, analysis, and inference, as well as providing explanations based on conceptual, methodological, or contextual grounds. Critical thinking also includes the ability to solve complex problems into simpler parts, analyze the validity of arguments including hidden premises and biases, and draw general principles through data-driven induction. Additionally, critical thinking involves creating structured arguments, considering various points of view, and evaluating existing alternatives.

In education, critical thinking skills are a key need that supports strategic decision-making, especially in a dynamic and complex environment. (Hiltrimartin et al. 2024) It shows that

group discussions and collaborative learning are effective strategies in improving critical thinking skills. Through collaboration, students can listen to other perspectives, dialogue, and evaluate diverse problem-solving approaches, all of which contribute to analytical and evaluative abilities. However, mathematics teaching in Indonesia often focuses on abstract theoretical approaches, making it difficult for students to understand and apply mathematical concepts in daily life (Gravemeijer and Doorman 1999). This situation widens the gap between the teaching of mathematics in schools and its application in real contexts (Freudenthal and Gottlieb 1991).

Research (Zubainur et al. 2020) shows that the use of local cultural elements in RME learning increases students' involvement and understanding of mathematical concepts. In addition, the study (Zubaidah A. et al. 2021) found that the RME approach not only improves mathematical reasoning abilities, but also strengthens mathematical communication skills. The concept of horizontal and vertical mathematization in RME allows students to develop concepts from concrete contexts to formal forms, enriching their understanding as well as providing tools for the application of concepts in a variety of situations (Gravemeijer and Doorman 1999).

In the context of local culture, the application of RME can enrich the learning experience of students. Example, (Mariamah et al. 2021) show how geometric shapes in the design of Lambitu tribal traditional houses help students understand geometry in the context of a culture they are familiar with. Study (Zuliana et al. n.d.; Zuliana et al. n.d.; Irawan et al. 2019) It supports these findings by showing that cultural elements such as batik patterns and traditional houses make learning more interesting, while reducing anxiety about math. Based on various literature, this study aims to explore how the local culture-based RME approach can contribute to the development of students' critical thinking skills in Indonesia. This research underscores the importance of a relevant and contextual educational approach to support student learning outcomes more optimally.

Research Methods

This research uses the Research and Development (R&D) method as explained by (Prof. Dr. Sugiono 2009), with the aim of creating or developing new products that are effective in solving learning problems, especially in improving students' critical thinking skills. The development model used is the ADDIE Model (Analysis, Design, Development, Implementation, Evaluation) (Branch 2010), which is a systematic approach in instructional design. The ADDIE model was chosen because of its flexibility and wide application in various educational contexts, including the development of local culture-based learning materials. Research has previously shown the successful implementation of the ADDIE model, as revealed in a study by (Spatioti et al. 2022) (Spatioti et al. 2022)

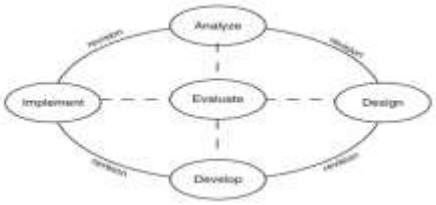

Figure 1. Concept ADDIE

The development process of Realistic Mathematics Education (RME)-based learning modules follows the following steps (Figure 1):

- Analysis Stage

- Design Stage
- Development Stage
- Implementation Stage
- Evaluation Stage.

The research was conducted in **SMP Muhammadiyah 04 Medan**, A school known for its innovation in the development of learning methods. This location was chosen because of its suitability for the implementation of RME-based learning modules that are integrated with local culture. The research covers the entire series of processes from the preparation stage, implementation, to the evaluation of learning outcomes.

The subjects of the study were 30 grade VIII students, who were selected because their level of cognitive ability was considered adequate to learn complex mathematical concepts, such as geometry and local culture-based applications. Grade VIII students are also at an ideal age for the development of critical thinking skills, which is the main focus of this study.

Table 1. Table Score

Skor	Category
5	Highly Worthy
4	Proper
3	Quite Decent
2	Not Eligible
1	Very Unworthy

To calculate the average score of each aspect of the assessment of material experts and media experts, the formula is used: **Mean ($\bar{x}$) = Σx / N**
Information:
$\bar{x}$: Average score
Σx : Total Score
N : (Respondent× Indicator)

The validation results are classified based on interpretation criteria, with the module feasibility level expressed in percentage form. To qualitatively interpret the average number of scores for each aspect using criteria, here are the criteria for score conversion:

Table 2. Average Score Number Conversion Formula

Value	Score	Category
5	$x > xi + 1{,}80\ SBi$	Highly Worthy
4	$xi + 0{,}60SBi < x \leq xi + 1{,}80SBi$	Proper
3	$xi - 0{,}60SBi \leq x \leq xi + 0{,}60SBi$	Quite Decent
2	$xi - 1{,}80SBi < x \leq xi - 0{,}60SBi$	Not Eligible
1	$x \leq xi - 1{,}80\ SBi$	Very Unworthy

Information:
x = Empirical/Actual Score
xi = Ideal Average
xi = 1/2 (Maximum score + Minimum score)
SBi = Ideal standard deviation
SBi = 1/6 (Maximum score – Minimum score)

Meanwhile, the formula to calculate the average percentage of assessments from material experts and media experts is used as follows: **$xi = \Sigma x / Smax \times 100\%$**
Information:
Smax : Maximum Score
ΣS : Total Score
xi : Assess the feasibility of each aspect of the questionnaire

Table 3. Learning Media Eligibility Scale

Presents	Criteria
> 81%	Highly Worthy
61% < x ≤ 80%	Proper
41% < x ≤ 60%	Quite Decent
21% < x ≤ 40%	Less Worthy
≤ 20%	Very Unworthy

Results and Discussion

The learning module designed in this study integrates the Realistic Mathematics Education (RME) approach with local cultural elements typical of South Tapanuli. This module was developed to improve students' critical thinking skills by using cultural contexts that are relevant and familiar to them. The main focus of this module is mathematics material, specifically geometry, which is presented through cultural elements such as the geometric patterns of ulos fabrics, the structure of traditional houses, and traditional games such as marsitekka and marsibodoh.

Each chapter in the module is designed to provide an introduction to culture that introduces students to relevant local cultural elements. After the introduction to culture, students are directed to systematic and interactive learning activities. This activity aims to encourage students to analyze cultural patterns, Understand the relationship between cultural elements and mathematical concepts, Connecting cultural values with daily life.

Thus, this module not only serves as a mathematics teaching material but also as a learning medium to instill students' love for their local culture. This module is enriched with the use of technology through the GeoGebra application. This app helps students visualize culture-based math concepts in a more interactive way. Some of the advantages provided by GeoGebra in this module are Digital Representation, Concept Visualization, Self-Paced Learning

In addition, the guide for teachers is designed with a comprehensive teaching strategy. Teachers can utilize GeoGebra to facilitate culture-based learning in a more engaging and efficient way. This combination of local cultural elements and technology ensures that the modules provide an innovative, contextual and relevant learning experience. In the design stage, modules are designed with systematic steps to meet the needs of students and support learning objectives.

The use of ulos cloth in mathematics learning not only strengthens students' understanding of geometry concepts but also deepens their appreciation of local cultural heritage. This supports learning objectives that are not only academically oriented but also on the formation of students' character through the introduction of cultural values, for example is the following figure 2:

Figure 2. Example of the context of reflection on the Ulos Fabric Pattern

Based on Figure 2, it is assumed that there is a point A on the ulos fabric pattern with coordinates (3, 2).

Question:

- Determine the coordinates of the shadow of point A if it is reflected against the Y axis.
- Specify the coordinates of the shadow of point A if it is reflected against the X axis.

Solutions:

- The reflection on the Y axis changes the coordinates (x, y) to (-x, y). So, the shadow of point A is (-3, 2).
- Reflection on the X axis changes the coordinates (x, y) to (x, -y). So, the shadow of point A is (3, -2).

Solutions with geogebra applicators

This module utilizes GeoGebra to visualize the reflection of point A on the coordinate axes. With GeoGebra, students can:

- See the reflection process directly in the form of digital graphics.
- Understand how coordinates change during transformation.
- Connecting theoretical concepts with interactive visualizations to improve their conceptual understanding.

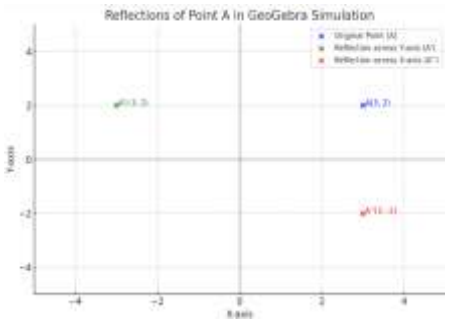

Figure 3. GeoGebra Simulation

The simulation in GeoGebra (Figure 3) shows how point A with initial coordinates (3,2) is projected to its shadow position on the X and Y axes. This approach makes learning more interactive, engaging, and relevant to the cultural context used in the modules. This combination of learning mathematics and local culture not only makes the learning process more contextual and interesting, but also becomes an important foundation for training students' critical thinking skills in facing modern challenges.

RME-based learning modules that integrate the culture of South Tapanuli have proven to be effective in improving students' understanding of mathematical concepts and critical thinking

skills. Validation and implementation showed that the module was culturally relevant and capable of providing an innovative and meaningful learning experience. The combination of culture-based learning and technology creates an approach that not only strengthens academic learning outcomes but also enriches students' character through an appreciation of local culture.

Learning Analysis Results

Figure 4. Comparison of Student Learning Outcomes (RME-based modules)

The graph (Figure 4) shows a comparison of student scores before and after the learning intervention using the Realistic Mathematics Education (RME)-based module.

- Before the Intervention (blue line): The student's score ranges from 65 to 80, with fluctuations indicating variations in the student's initial understanding of the material.
- After the Intervention (red line): Student scores improved significantly, ranging from 85 to 100, with almost all students achieving higher outcomes compared to before learning.

Key Takeaways:

- Score Improvement: There was a consistent improvement in student scores after the intervention, with an average increase of 22.25%.
- Maximum Performance: Most students achieve scores close to or equal to perfect grades after learning.
- Module Effectiveness: This graph shows that RME-based modules that integrate local culture are effective in improving students' understanding and learning abilities.

Overall, learning interventions with RME-based modules have a significant positive impact on student learning outcomes.

Distribution of Student Learning Outcomes

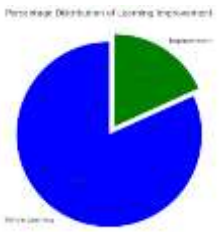

Figure 5. Distribution of Percentage Improvement in Student Learning Outcomes

This pie graph depicts the distribution of percentage student learning outcomes before and after the learning intervention using RME-based modules.

- Before Learning (81.8%): Most of the students' learning outcomes come from early performance before learning.

- Increase (18.2%): As many as 18.2% of the total distribution showed an increase in learning outcomes achieved after the implementation of the module.

These data show that local culture-based learning interventions and RME approaches contribute significantly to improving student understanding, although early results still dominate the total distribution. This increase reflects the positive impact of modules on learning outcomes. The implementation process of the module based on Realistic Mathematics Education (RME) which is integrated with the culture of South Tapanuli notes various important aspects that are indicators of module success. Overall, the observation aspects show that this module is not only effective in improving student learning outcomes but also able to create relevant, interactive, and meaningful learning. Nevertheless, the evaluation of the existing limitations provides an opportunity for the improvement of the module to be more adaptive to the needs of students and the learning context. With the integration of local cultural elements and technology, this module has succeeded in becoming an innovative and feasible learning tool to be applied more widely.

Student Engagement Graph

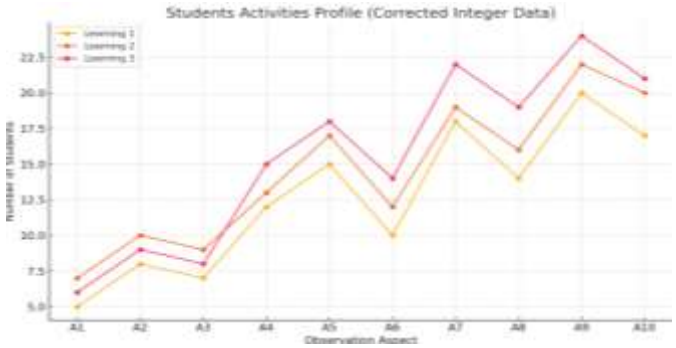

Figure 6. Student Activity Profile Based on Observation Aspects During Learning

The graph shows the student activity profile based on ten aspects of observation (A1–A10) during three learning sessions: Learning 1, Learning 2, and Learning 3.

- Learning 1 (Orange): Student activities start from a low level, especially in the early aspects (A1 to A3). However, there is a gradual improvement in the next aspect.
- Learning 2 (Red): The increase in student engagement is more significant than the first session, especially in aspects A6 to A10.
- Learning 3 (Pink): This session showed the best results with high student engagement in almost all aspects, especially on A9 and A10.

The graph shows the trend of increasing student engagement over the three learning sessions, reflecting the success of the module in increasing active participation and learning relevance. Observations revealed that students were more enthusiastic when using GeoGebra to explore mathematical concepts associated with local culture. Students find learning more interesting and easy to understand because of the cultural context that is relevant to daily life. Teachers also gave positive feedback, stating that this module facilitates teaching while improving student interaction in the classroom.

Improvement steps based on suggestions and feedback from teachers and students aim to ensure that modules remain materially relevant and effectively support learning. Consistency in connecting local cultural elements with mathematical concepts is the key to creating meaningful and adaptive learning, so that learning goals can be achieved optimally.

Discussion

Educational resources are a strategic element in improving the quality of learning. According to (Sutarni et al. 2024), Realistic Mathematics Education (RME)-**based modules** make a significant contribution in improving students' higher-order thinking skills through contextual activities that are relevant to daily experiences. In this study, the learning module based on the local culture of South Tapanuli is not only designed to improve the understanding of mathematical concepts, but also to support the formation of students' character through appreciation of local culture. Learning strategies also play a crucial role. (Sa'id et al. 2021) stated that RME-based learning strategies through challenging tasks improve students' mathematical communication skills. (Rohaeti et al. 2020) adding that the local culture-based approach not only improves understanding but also instills character values in students, such as a love for their cultural heritage. The RME approach that integrates local culture, such as the geometric patterns of ulos cloth and the structure of South Tapanuli traditional houses, provides a new dimension in mathematics learning. This module helps students relate abstract mathematical concepts to cultural patterns that are familiar to them. For example, ulos cloth is used to explain the concept of reflection and rotation (Figures 2 and 3). Through the use of GeoGebra, students can visualize geometric transformations dynamically, making learning more interactive and relevant. According to (Zubainur et al. 2020) The local culture-based approach increases student engagement in learning. This is reflected in the activity profile of students (Figure 6), where engagement increases significantly from the first learning session to the third session. In the third session, the aspects of motivation (A9) and learning contextualization (A10) showed the highest student involvement. The validation results show this module is very feasible with an average score Filling Capacity: 4.8, Cultural Relevance: 4.9, Instruction Clarity: 4.7, Media Visualization: 4.6 With a feasibility percentage of over 81%, this module meets the "Very Feasible" criteria to apply in the classroom. The implementation results also showed an increase in student learning outcomes, with the average score increasing from 73.1 to 89.37 (an increase of 22.25%). The data on the distribution of student learning outcomes (Figure 5) showed an 18.2% improvement in student comprehension after the implementation of the module, reinforcing the effectiveness of this approach. This module has the potential to be applied in other regions with the adjustment of local cultural elements. For example, geometric patterns on Javanese batik, Minangkabau traditional house structures, or traditional Toraja ornaments can be used to explain other mathematical concepts, such as symmetry, translation, or dilation. With this refinement, modules can be more adaptive to the needs of students with diverse abilities.

Conclusion

This research produced a learning module based on Realistic Mathematics Education (RME) that integrates the local culture of South Tapanuli to improve students' critical thinking skills. This module is designed using the ADDIE model, covering requirements analysis, design, development, implementation, and evaluation. The validation results showed that this module was very feasible with an average score of 4.6 to 4.9, while the implementation showed an increase in the average score of students by 22.25%. This module has proven to be effective in developing critical thinking skills through four indicators: analysis, evaluation, inference, and problem solving. The use of GeoGebra supports the visualization of mathematical concepts in an interactive manner, making learning more interesting and relevant. The integration of local culture in the module not only strengthens students' understanding of mathematical concepts but also instills character values, such as a love for local culture. This module has the potential to be applied in various regions with adjustments to local cultural elements, making it a relevant innovation for mathematics education in Indonesia.

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