



Practicality of a batak toba culture-based realistic model in the higher-order thinking skills of pre-service elementary school teachers

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Article info	Abstract
Keywords: Realistic mathematics education, batak toba culture, higher-order thinking skills, teacher education, practicality	This study evaluates the practicality of a Realistic Mathematics Education model integrated with Batak Toba cultural elements to develop Higher-Order Thinking Skills among pre-service elementary school teachers. Using a Research and Development (R&D) design based on Plomp's three-phase model, the research involved preliminary investigation, design and development, and evaluation. The model was validated through expert judgment, pilot testing, and classroom trials. Practicality was assessed using indicators of implementation, ease of use, student engagement, and practitioner acceptance. Results from two trials showed significant improvements: implementation increased from 3.2 to 4.5, lecturer ease from 3.1 to 4.4, student engagement from 3.0 to 4.3, and practitioner acceptance from 3.3 to 4.6 (scale 1–5). Students' HOTS improved from a moderate category (0.63) in the first trial to a high category (0.85) in the second. These findings indicate that the Batak Toba culture-based RME model is practical, culturally relevant, and pedagogically effective, with strong potential for integration into teacher education programs.

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1. Introduction

Education is one of the main pillars in improving the quality of competitive human resources globally. In the context of the 21st century, education faces new challenges in which students are not only required to master factual and procedural knowledge but are also expected to develop Higher Order Thinking Skills (HOTS). These skills include the ability to analyse, evaluate, and create (Anderson & Krathwohl, 2001), which serve as essential provisions for young generations in dealing with the complexities of real-life problems. For pre-service elementary school teachers, mastery of HOTS holds even greater significance, as they serve as the main facilitators in fostering critical, logical, and creative thinking in children from an early age. Thus, the quality of HOTS among teacher candidates directly impacts the success of elementary education in producing a generation capable of critical, adaptive, and innovative thinking.

However, empirical evidence indicates that the HOTS of teacher education students remain relatively low. Previous studies have revealed that the learning process in teacher education institutions often procedurally emphasises mastery of concepts, leaving students less accustomed

to dealing with contextual and challenging problems (Saragih & Napitupulu, 2015). This condition is further reinforced by international assessments such as the Programme for International Student Assessment (PISA, 2018) and the Trends in International Mathematics and Science Study (TIMSS, 2019), showing that Indonesian students' critical thinking and mathematical reasoning skills are still weak. These findings reflect a significant gap between the demands of the 21st-century curriculum and the actual classroom practices, including those in teacher education institutions. This situation poses a serious challenge, as teacher candidates who are not trained in developing HOTS struggle to instil these skills in their future students.

One approach considered effective in addressing this challenge is the Realistic Mathematics Education, which is an adaptation of the Realistic Mathematics Education theory developed by Freudenthal (1991). This approach is based on the view that mathematics is a human activity, and therefore, mathematics learning should be closely linked to real-life situations (Gravemeijer, 1999). By providing meaningful contexts, students can construct their own conceptual understanding through mathematical activities that are relevant and authentic. Several studies have demonstrated that implementing Realistic Mathematics Education can enhance problem-solving skills, conceptual understanding, and learning motivation (Widjaja, 2013; Wijaya, 2017). Thus, applying Realistic Mathematics Education in teacher education has the potential to become a crucial strategy in fostering HOTS while strengthening the relevance of learning to everyday life.

In addition to a realistic approach, integrating local culture into mathematics learning also represents a strategic effort aligned with the education needs in Indonesia. This perspective aligns with ethnomathematics, as introduced by D'Ambrosio (2006), which emphasises that culture is a valuable resource in constructing meaningful learning experiences. Ethnomathematics highlights that traditions, symbols, and cultural practices contain mathematical values that can be explored to support conceptual mastery while simultaneously reinforcing students' cultural identity. Consequently, learning does not merely train cognitive skills but also cultivates pride in local wisdom and cultural heritage.

As regards the possibility, the Batak Toba culture holds significant potential to be integrated into mathematics learning. Various Batak Toba cultural artefacts, such as Gorga carvings, Ulos Patterns, and Kinship Systems, are embedded with rich mathematical principles that can serve as contextual teaching materials. For example, geometric patterns in Ulos can be used to understand concepts such as symmetry, proportion, and transformation. At the same time, the kinship system can serve as a context for learning about sets or relations. Recent studies confirm that culturally-based mathematics learning effectively enhances students' motivation, interest, and critical thinking skills (Risdiyanti & Prahmana, 2020; Rosa & Orey, 2016). These findings indicate that integrating Batak Toba culture into mathematics education is relevant and strategically enriching HOTS-oriented learning.

Therefore, developing a mathematics learning model based on the Batak Toba culture through the Realistic Mathematics Education approach is considered an innovative effort to address the low HOTS among pre-service elementary school teachers. This model aims to improve the quality of mathematics learning, cultivate appreciation for local cultural values, and strengthen national character. Furthermore, this study is expected to theoretically contribute to developing ethnomathematics and practically enrich teacher education strategies in Indonesia.

2. Literature review

2.1 Realistic mathematics education approach

Freudenthal's (1991) realistic mathematics education approach emphasises that mathematics should be experienced as a human activity rooted in reality rather than abstract symbols. According to Gravemeijer (1999), learning begins with real-world problems that are meaningful and familiar to

students. This approach promotes exploration, reflection, and the meaningful application of mathematics in daily life.

Incorporating Batak Toba culture into mathematics instruction aligns with RME principles by embedding learning in students' experiences. For instance, traditional kinship systems (Saragih & Napitupulu, 2015) can teach sets and relations, while geometric motifs in ulos fabrics and carvings illustrate symmetry and transformation (Suryadi, 2019). This cultural integration contextualises abstract concepts and fosters deeper cognitive engagement (Vygotsky, 1978).

Educational theories by Bandura (1977) and Vygotsky (1978) highlight that learning is more effective when tied to students' social and cultural contexts. Learning anchored in familiar cultural structures enhances student motivation and encourages the construction of knowledge through meaningful participation (Gay, 2018). Thus, a culturally informed RME approach makes mathematics more accessible and promotes the development of critical thinking.

2.2 Higher order thinking skills (HOTS) in mathematics learning

Higher order thinking skills (HOTS)—analysing, evaluating, and creating—are central to 21st-century education (Anderson & Krathwohl, 2001). These skills are essential in mathematics learning for developing students' ability to solve complex problems and adapt knowledge across varied contexts (Silver, 2000).

Traditional, rote-based teaching methods often fail to cultivate these higher-order capabilities. Hadi (2018) notes that such methods emphasise correct answers over critical reasoning. In contrast, learning strategies that integrate problem-solving and student-centred inquiry promote cognitive engagement and skill transferability (Saavedra & Opfer, 2012).

Cultural contexts can be powerful media for HOTS development. For example, deliberation traditions in Batak Toba communities involve critical analysis, weighing alternatives, and making collective decisions, processes directly aligned with HOTS domains (Saragih & Napitupulu, 2015). When mathematical tasks are embedded in culturally relevant scenarios, students are more likely to practice analytical reasoning and creative problem-solving (Ladson-Billings, 2021).

Thus, fostering HOTS requires a departure from procedural instruction toward experientially grounded and culturally meaningful learning, enabling students to become critical thinkers and adaptable problem-solvers.

2.3 The role of batak toba culture in mathematics education

As D'Ambrosio (2006) emphasises, culture provides a cognitive framework that influences how students perceive and engage with mathematical content. Cultural values, symbols, and practices can serve as bridges to help students relate abstract mathematical concepts to their everyday lives (Gay, 2018).

In the Batak Toba cultural context, geometric patterns in traditional arts such as Gorga carvings and Ulos textiles can teach concepts like symmetry, transformation, and spatial reasoning (Suryadi, 2019). Meanwhile, the Marga (clan) system offers a relatable framework to understand hierarchical relations and set theory (Saragih & Napitupulu, 2015).

This approach aligns with sociocultural learning theories, particularly those proposed by Vygotsky (1978), who emphasised that knowledge is constructed through social interaction and cultural mediation. Learning experiences embedded in students' cultural narratives allow for more meaningful engagement, promote identity affirmation, and deepen conceptual understanding.

By integrating local culture into mathematics education, students are more likely to see mathematics not as an abstract school subject but as a tool embedded in their community and cultural practices. This improves comprehension and supports equity and inclusivity in education by recognising and validating cultural diversity within the curriculum (Ladson-Billings, 2021).

3. Method

3.1 Research design

This study adopts a Research and Development (R&D) methodology to design, validate, and evaluate a culturally integrated mathematics learning model that enhances Higher-Order Thinking Skills (HOTS) among pre-service elementary school teachers. The development process follows the three-phase model proposed by Plomp (2013), which includes: (1) preliminary investigation, (2) design and development, and (3) evaluation and reflection.

A comprehensive needs analysis is conducted through literature review, classroom observations, and stakeholder interviews in the preliminary investigation phase. This phase examines theories of Realistic Mathematics Education (Freudenthal, 1991; Gravemeijer, 1999), HOTS development (Anderson & Krathwohl, 2001), and culturally responsive pedagogy (Gay, 2018; Ladson-Billings, 2021). It also explores local cultural contexts, particularly the Batak Toba culture (Saragih & Napitupulu, 2015; Suryadi, 2019), to identify potential integration into mathematics instruction.

The design and development phase entails creating a learning model that incorporates local cultural elements and is aligned with the principles of Realistic Mathematics Education. This phase follows an iterative process that includes expert validation, formative evaluation, and pilot testing (Sugiyono, 2017). The expert validation stage engages subject matter experts to assess content validity, pedagogical soundness, and cultural alignment. Revisions are made accordingly before proceeding to small-scale trials.

The final phase, evaluation and reflection, aims to determine the model's effectiveness, practicality, and scalability. The model is tested in authentic classroom settings with larger groups of participants. Data are collected through pre-tests, post-tests, observations, questionnaires, and interviews and analysed using mixed-methods approaches (Creswell & Plano Clark, 2018). The results refine the model and offer recommendations for broader implementation in teacher education programs.

3.2 Expert group

The expert group plays a vital role in ensuring the quality and relevance of the developed model. It comprises three categories of experts: (1) mathematics education experts, (2) Batak Toba cultural experts, and (3) educational practitioners. Mathematics education experts assess alignment with principles (Zulkardi, 2002), while cultural experts evaluate the appropriateness of integrated cultural content (Saragih & Napitupulu, 2015). Practitioners, lecturers, and teachers examine classroom feasibility and instructional strategies (Suryadi, 2019).

Validation procedures involve Focus Group Discussions (FGDs), expert panels, and validation instruments to assess model feasibility, content clarity, and implementation ease (Plomp & Nieveen, 2013). Feedback gathered from these procedures informs revisions to enhance theoretical grounding, cultural sensitivity, and instructional practicality.

Additionally, the experts provide insights into teaching strategies that foster HOTS. For example, suggestions include integrating contextual problem-solving tasks, interactive group activities, and culturally anchored mathematical scenarios (Saavedra & Opfer, 2012; Ladson-Billings, 2021). This collaborative and interdisciplinary approach ensures that the final product meets future elementary school teachers' academic, cultural, and pedagogical needs.

3.3 Research procedure

The research procedure follows a systematic and iterative process, beginning with a literature review and contextual analysis. This stage involves analysing core concepts such as (Zulkardi, 2002; Gravemeijer, 1999), HOTS development (Anderson & Krathwohl, 2001), and culturally responsive teaching (Gay, 2018; D'Ambrosio, 2006), as well as identifying Batak Toba cultural elements suitable for integration into math instruction (Suryadi, 2019).

After the review, the initial model, which includes learning scenarios, teaching materials, and HOTS assessment instruments, was developed. The model undergoes expert validation through FGDs and structured feedback using standard validation instruments (Plomp & Nieveen, 2013). Revisions are made before a limited trial in a small group of pre-service teachers. Data from observations, interviews, and reflective journals are collected and analysed thematically (Miles, Huberman & Saldaña, 2014).

The final stage is large-scale implementation, which evaluates the model's performance across diverse learning contexts. The model is applied in several teacher education institutions to examine its scalability and impact on student performance. Both quantitative methods (e.g., pre-/post-test comparisons, statistical analysis) and qualitative methods (e.g., focus group feedback, classroom discourse analysis) are used to determine effectiveness (Creswell & Plano Clark, 2018).

Through this structured process, the research aims to produce a validated, culturally responsive mathematics learning model that is pedagogically effective and contextually grounded for Indonesian elementary teacher education.

3.4 Practicality test indicators of the learning model

The practicality of the Realistic Mathematics Education model based on the Batak Toba Culture was measured based on the assessments of several experts and practitioners (lecturers of the Advanced Elementary Mathematics Education course). The evaluation was grounded on their theoretical expertise and practical experience in determining whether the model could be feasibly implemented in the field, considering its components and the learning tools provided. The average score was determined from the mean values given by the experts. This mean score was then referred to the interval of practicality levels of the PMRI learning model based on the Batak Toba Culture, as shown in the following table:

Table 1. Practicality test of the learning model

I Ease of Implementation	
1	Clarity of instructions: Teachers can easily understand the model's guidelines and procedures.
2	Ease of schedule adjustment: The model can be applied within the allocated learning time.
3	Compatibility with School Environment: The model fits the existing situation and facilities of the school.
II Efficiency of time and resources	
1	Utilisation of available resources: The model can use existing facilities and materials.
2	Cost Efficiency: The model does not require significant additional costs for schools or teachers.
3	Time Efficiency: The model does not take more time than scheduled.
III Flexibility	
1	Ease of material adjustment: The model allows teachers to adapt materials to students' comprehension levels.
2	Adaptability to various class types: The model can be applied to classrooms with diverse characteristics regarding student abilities and available facilities.
3	Suitability with teaching styles: The model supports variations in teaching methods, allowing teachers to adapt it to their style.
IV Ease of use	
1	Clarity of steps: Each step in the model is clearly presented and easy to follow.
2	Availability of guidelines: The model is equipped with sufficient guidance to explain each implementation stage.
3	User-friendliness: The model's components (teaching materials, tools, methods) are easy to operate and user-friendly.
V Alignment with learning objectives	

1	Relevance of Activities to Learning Objectives: Each activity directly relates to the intended learning outcomes.
2	Consistency in Assessment: The assessment tools and techniques support measuring learning objectives.
3	Support for Core Competencies: The model is designed to help students master core competencies effectively.
VI	Attractiveness
1	Engaging Activities: The model provides varied and interesting activities to prevent student boredom.
2	Student Engagement: The model increases students' active participation in the learning process.
3	Visual and Presentation Appeal: Model components, including media and teaching aids, are designed with attractive visuals.

Table 2. Practicality level according to experts

Score ranges	Descriptions
$1 \leq IP < 2$	Very Low
$2 < IP < 3$	Low
$3 < IP < 4$	Moderate
$4 \leq IP < 5$	High
$IP = 5$	Very High

Adapted from Sinaga, 2007

Table 2 reveals that IP stands for the intended $\leftrightarrow$ perceived practicality of the PMRI learning model based on the Batak Toba culture. The model is considered to have good practicality if it achieves at least the "high" category. If the practicality level falls below "high," revisions must be made based on feedback from experts and practitioners. Reassessment is then conducted until the model reaches the ideal level of practicality.

3.5 Indicators of HOTS skill test

The measurement of students' Higher-Order Thinking Skills (HOTS) aimed to reflect their skill achievement, with an orientation on improving the level of HOTS attained. The model is highly effective if 80% of students participating in the learning process achieve the predetermined success benchmark indicators.

Table 3. HOTS Indicators

No	HOTS Aspects	Assessment indicators	Criteria	Score
1	Analysing	Problem Solving: Ability to break down complex problems into simpler elements	Ability to decompose complex problems	5
2	Analysing	Identifying Patterns and Relationships: Ability to find trends or patterns in information	Ability to identify trends or patterns	2
3	Analysing	Evaluating Arguments: Ability to assess the strengths and weaknesses of proposed arguments or solutions	Ability to evaluate argument validity	3
Total score				10
4	Evaluating	Breaking Down Information: Ability to break down complex arguments into elements to understand their structure	Ability to break down complex information	5
5	Evaluating	Identifying Patterns and Relationships: Recognising how data elements are interrelated	Ability to recognise interconnections	2
6	Evaluating	Structural Assessment: Assessing the overall effectiveness of information/argument structures	Ability to assess structural coherence	3

Total score				10
7	Creativity	Fluency: The capacity to generate a large number of ideas quickly	Productivity of ideas	5
8	Creativity	Flexibility: Ability to shift focus between categories of ideas	Ability to switch approaches	2
9	Creativity	Originality: Ability to generate unique and uncommon ideas	Ability to create novel ideas	3
Total score				10

Based on these references, the mastery criterion for students' HOTS using the PMRI learning model based on the Batak Toba culture is that students must achieve a moderate mastery level, with a minimum score of 60 out of 100 across two HOTS tests. Furthermore, classical mastery is achieved if at least 80% of students reach this minimum threshold.

Table 4. HOTS Ability level of students in the pmri learning model based on the batak toba culture

Score range	Description
$0 \leq TP < 40$	Very Low
$40 \leq TP < 60$	Low
$60 \leq TP < 75$	Moderate
$75 \leq TP < 90$	High
$90 \leq TP \leq 100$	Very High

Adapted from Sinaga, 2007

Table 4 presents that TP refers to the HOTS Ability Level of Elementary Teacher Education students. If the criteria are unmet, the teaching and learning process must be reviewed and revised based on discussions with partner lecturers. Further trials are conducted to achieve an effective PMRI learning model based on the Batak Toba Culture regarding students' HOTS ability.

3.6 Calculation of HOTS improvement (n-gain test)

To calculate the improvement of students' HOTS after participating in the Elementary Mathematics Education course by implementing the PMRI learning model based on the Batak Toba culture, a normalised gain test (N-Gain) was used, comparing pre-test, post-test, and ideal scores. The formula is as follows:

$$N - Gain = \frac{Posttest\ Score - Pretest\ Score}{Ideal\ Score - Pretest\ Score}$$

Description:

Ideal Score means the maximum score.

The categorisation of N-Gain values is shown in the following table:

Table 5. N-gain interpretation criteria

N-Gain value	Categories
$0.7 \leq g \leq 1.00$	High
$0.3 \leq g \leq 0.7$	Moderate
$g < 0.3$	Low

Source: Meltzer, 2003

4. Results

This study evaluates the practicality of implementing the Realistic Mathematics Education model based on the Batak Toba culture in the mathematics learning process for pre-service elementary school teachers. The model's practicality is assessed through several aspects, including its implementation in learning, lecturers' ease of implementation, student engagement during learning, and acceptance of the model by education practitioners.

4.1 Students' HOTS ability

The following tables present the test data on students' Higher-Order Thinking Skills (HOTS) ability are presented in the following tables. The average HOTS scores in the Advanced Elementary Mathematics Education course are below.

Table 6. Students' hots skills after being taught using the realistic mathematics education model based on the batak toba culture

No. Respondent	Proportion		Students' HOTS skill level
	Pre-test	Trial 1	
Average	0.20	0.63	Moderate

Based on the data analysis in the table above, it can be described that, classically, the level of HOTS mastery among students of the Elementary School Teacher Education Study Program in the Advanced Elementary Mathematics Education course (geometry topic) is very low, with a HOTS proportion of 0.20. The comparison of students' HOTS levels after being taught using the Realistic Mathematics Education model based on the Batak Toba culture shows an increase, yet still in the moderate category, with a HOTS proportion of 0.63 or 63%. Individually, nine pre-service teachers are in the low category, and 26 are in the mild category.

The percentage of students with at least a moderate mastery level was 74% out of 35. This percentage was obtained by dividing the number of students with at least moderate mastery by the total number of trial subjects. Referring to the mastery criteria of the learning program, it can be concluded that learning the geometry topic has not yet achieved classical mastery.

Table 7. Students' HOTS skills after being taught using the realistic mathematics education model based on the batak toba culture

No. Respondent	Proportion		Students' HOTS skill level
	Trial 1	Trial 2	
Average	0.63	0.85	High

Based on the data analysis in the table above, it can be described that, classically, in Trial 1, students' HOTS mastery in the Elementary School Teacher Education Study Program for the Advanced Elementary Mathematics Education course (geometry topic) is at a moderate level, with a HOTS proportion of 0.63. After revisiting the application of the Realistic Mathematics Education model based on the Batak Toba culture in Trial 2, there is a significant improvement, with a HOTS proportion of 0.85 or 85%, categorised as high. Individually, one pre-service teacher has a moderate mastery level, 25 have high mastery, and nine have very high mastery.

The percentage of students with at least high mastery among 35 students was 3% at a moderate level, 71% at a high level, and 26% at a very high level. This percentage was obtained by dividing the number of students with at least high mastery by the total number of trial subjects. Referring to the mastery criteria established in Chapter III, it can be concluded that learning the geometry topic has achieved classical mastery.

4.2 Implementation of the model in learning

The effectiveness of implementing the model is a key indicator in assessing the practicality of an educational innovation. Based on observation data collected during the learning process, the first trial resulted in an average score of 3.2 (on a scale of 5), which falls into the "moderately practical" category. Some of the main challenges encountered at this stage included students' adaptation to the culturally integrated approach, particularly in linking mathematical concepts to the Batak Toba culture. Additionally, lecturers faced difficulties adjusting their teaching strategies to align with culturally realistic learning principles.

After revising the model design and providing additional training for lecturers, the second trial showed a significant improvement, with the implementation score rising to 4.5 ("highly practical"). This improvement indicates that the model can be effectively applied in mathematics learning for pre-service elementary school teachers with enhanced implementation guidelines and strengthened culturally integrated teaching materials.

4.3 Ease of implementation by lecturers

The ease of model implementation by lecturers is a crucial factor in the success of any learning innovation. Survey data from lecturers in the first trial indicated an ease-of-implementation score of 3.1, suggesting that the model required further refinements to facilitate its application in university courses. Lecturers reported that while the concept was based on the Batak Toba culture, it was engaging, but they needed more detailed guidance on integrating local cultural elements into mathematics instruction.

Following modifications to the learning modules and additional workshops for lecturers, the second trial showed a score increase to 4.4, indicating that with adequate resources and more straightforward implementation guidelines, lecturers can successfully apply the model in teaching mathematics to pre-service elementary school teachers.

4.4 Student engagement during learning

Student engagement during learning is another critical factor in assessing the model's practicality. In the first trial, student engagement was relatively low, with a score of 3.0, as many students struggled to translate cultural elements into mathematical concepts, particularly in applying culture-based problem-solving strategies.

After modifying the learning scenarios and providing more concrete examples of how the Batak Toba culture connects to mathematics concepts, student engagement significantly increased in the second trial, with a score of 4.3. Students became more actively involved in discussions, provided mathematically sound cultural arguments, and demonstrated improved critical and analytical thinking skills.

4.5 Acceptance of the model by education practitioners

The model's acceptance by education practitioners, including senior lecturers and mathematics education experts, is also an important indicator of its practicality. In the first trial, the survey results from practitioners showed an acceptance score of 3.3, indicating that while the model was perceived as innovative, certain aspects required refinement for broader adoption.

After making improvements based on practitioner feedback, the acceptance score increased to 4.6 in the second trial. Mathematics education experts acknowledged that this culture-based approach could effectively improve mathematical concept comprehension, particularly for pre-service teachers who can later teach in culturally rich regions.

4.6 Summary of research findings

The practicality improvements observed across various aspects of the study are summarised in the following table:

Table 8. Summary of research findings

Assessment aspect	Trial 1 score (scale of 5)	Trial 2 score (scale of 5)	Improvement (%)
Implementation of model	3.2	4.5	40.6%
Student engagement	3.0	4.3	43.3%
Ease of implementation by lecturers	3.1	4.4	41.9%
Acceptance by practitioners	3.3	4.6	39.4%

Table 8 reveals a significant improvement in all aspects of model practicality after revisions and refinements are made based on the first trial.

The research findings indicate that the model based on the Batak Toba culture can be effectively implemented in mathematics learning for pre-service elementary school teachers. This model enhances the effectiveness of learning implementation and facilitates lecturers in applying culture-based teaching strategies while increasing student engagement in contextual mathematical learning.

5. Discussion

This study explores the practicality of implementing the Realistic Mathematics Education model integrated with Batak Toba cultural elements in mathematics instruction for pre-service elementary school teachers. The model's practicality was evaluated based on four key indicators: its classroom implementation, ease of adoption by educators, student engagement, and acceptance by educational practitioners. The discussion below presents findings concerning relevant academic theories and prior studies.

5.1 Learning model of Indonesian realistic mathematics education based on Batak Toba culture

In general, the design stages of the Indonesian Realistic Mathematics Education learning model, based on the Batak Toba culture, are: cultural apperception; problem-solving discussion; *Suhi Ni Ampang Na Opat* social interaction pattern with representation and problem-solving; and reflection on learning outcomes. The lecturer's activities at each learning stage are presented in the table below.

Learning Outcomes:

Through the advanced elementary mathematics learning course, students are expected to:

5.1.1 Analyse mathematical material into its components and determine how these parts are connected to the overall structure or objective related to two-dimensional figures' properties, area, and perimeter.

5.1.2 Evaluate using criteria or standards for two-dimensional figures' properties, area, and perimeter.

5.1.3 Create elements to form a coherent or functional whole; reorganise elements into new patterns or structures related to two-dimensional figures' properties, area, and perimeter.

Table 9. Learning model of Indonesian realistic mathematics education based on Batak Toba culture

Stages/activities	Lecturer activities	Student activities	Time
Phase – cultural apperception (the use of context)	Condition for students to learn are attendance, class setting, and forming groups. Presents real-life problems using cultural experiences. Introduces	Students prepare for class and join groups. Students understand the problem and explore possible strategies. Students solve problems	37.5 minutes

	and guides students to solve real problems.	independently with guidance.	
Phase – problem solving (use of models, vertical instrument, student contribution)	Guide students to understand the problem. Provides scaffolding by giving hints or guiding questions.	Students attempt to solve problems using various strategies; engage in small group discussions using <i>Suhi Ni Ampang Na Opat</i> .	45 minutes
Phase – <i>Suhi Ni Ampang Na Opat</i> social interaction pattern with representation and problem solving (interactivity, intertwinement)	Observe the discussion process, guiding students to determine the best strategies and general principles.	Students present their work through <i>Suhi Ni Ampang Na Opat</i> interaction, training their confidence in expressing ideas.	45 minutes
Phase – reflection on learning outcomes	Guide students in concluding the problem-solving process, concepts, procedures, or principles built together.	Students formulate agreed-upon conclusions as strategies through class discussions.	22.5 minutes

According to Raihanah (2021), providing apperception at the beginning of every lesson is crucial for students' learning readiness. Apperception helps students focus, motivates them, and prepares them to absorb new knowledge. Mathematics is often perceived as complex and less interesting; therefore, perception is necessary to attract students' attention and readiness before learning begins. By doing so, lecturers can create the desired learning atmosphere and context. D'Ambrosio (2001) emphasised that mathematics can be better mastered when it is taught through cultural experiences drawn from students' daily lives. Therefore, linking mathematics with culture is essential to create meaningful learning.

The formation of learning groups applies the principles of *Suhi Ni Ampang Na Opat* philosophy and heterogeneity in terms of students' characteristics (ability and gender). In solving problems, the lecturer is a facilitator, motivator, and consultant, offering support when students face difficulties and embedding cultural values to encourage socio-cultural interactions. Research by Luka, Candiasa, & Aryanto (2019) found that group learning primarily aims to improve students' socialisation and collaboration, especially in problem-solving activities. It helps shy students to speak up and builds confidence in smaller groups. Training students to work in groups prepares them for adult life, where success often depends on collaboration.

In subsequent stages, the lecturer asks one or more groups to present their work results in class. Other groups are invited to provide feedback, critiques, and alternative solutions. The lecturer occasionally poses probing questions to test understanding. Groups chosen to present usually offer different answers, unique ideas, or valuable insights compared to others. This stage fosters open class discussion, cultivates Batak ancestral values, and encourages students to communicate ideas clearly. During presentations, students' understanding is tested by peers and the lecturer, leading to new perspectives and alternative solutions. This process strengthens objective reasoning and broadens problem-solving approaches. Furthermore, it trains students to confidently present ideas publicly, an essential competency in collaborative learning. According to Fuady (2016), reflective thinking includes retrospective analysis – the ability to recall and assess past experiences, problem-solving process – awareness of one's own learning, critical self-reflection – continuous self-improvement, and reflection on beliefs and achievements – recognising confidence and success as crucial problem-solving. At this final stage, students reflect on the learning process by

making conclusions about the new concepts based on mutual agreements reached during class discussions.

5.2 Implementation of the Model in Teaching

The practicality of an instructional model is closely tied to its successful execution in classroom settings. The findings revealed an improvement from moderate practicality in the initial trial to high practicality following revisions and contextual adjustments. This suggests that iterative design processes (Plomp & Nieveen, 2013) enhance model feasibility when adapted to specific classroom conditions.

The model's core principle—those mathematical concepts should be taught meaningfully and contextually—resonates with Realistic Mathematics Education, as articulated by Freudenthal (1991) and further elaborated by Gravemeijer (1999). Integrating Batak Toba cultural elements—ulos weaving patterns and traditional house structures—served as cognitive anchors that connected abstract mathematical ideas with students' everyday experiences.

This approach aligns with constructivist learning theory (Piaget, 1970; Vygotsky, 1978), emphasising that knowledge construction is most effective when rooted in learners' real-life contexts. Prior studies confirm that culturally relevant pedagogy improves content comprehension and increases relevance and motivation (Gay, 2018; Ladson-Billings, 2021). Therefore, implementing a culturally grounded model demonstrates high instructional value and aligns with previous empirical and theoretical insights.

5.3 Ease of Implementation by Educators

The ease of model implementation improved significantly between the two trials. Initially, educators faced moderate challenges, but implementation was rated very easy after receiving targeted training and technical support. This improvement underscores the importance of professional development programs in equipping teachers to adopt innovative instructional approaches (Guskey, 2002).

Effective adoption also depends on teachers' familiarity with local culture. Teachers with prior cultural knowledge could better interpret and integrate Batak Toba cultural artefacts into mathematics instruction. These findings echo research by Banks (2006), which emphasises that culturally competent educators can create more inclusive and engaging learning environments.

Moreover, the model's success supports the claim that teacher agency— the ability to interpret and adapt pedagogical strategies— is enhanced through culturally grounded training (Hollins, 2015). Consequently, these results validate earlier studies emphasising that teacher readiness and cultural understanding are critical to successful instructional model implementation (Saragih & Napitupulu, 2015; Suryadi, 2019).

5.4 Student Engagement During Learning

A notable increase in student engagement was observed between the initial and revised trials. Initially categorised as moderate, engagement rose to very high levels in the second trial. This enhancement was mainly due to familiar cultural contexts, which made abstract mathematical content more tangible and personally meaningful.

According to social learning theory (Bandura, 1986), learners are more motivated when instruction reflects their social and cultural realities. Integrating Batak Toba cultural elements provided an authentic and relatable learning experience, encouraging active participation, peer interaction, and deeper conceptual exploration.

Previous research has also established that culturally integrated instruction boosts critical thinking, collaboration, and conceptual mastery (Saavedra & Opfer, 2012; D'Ambrosio, 2006). This study's culturally anchored tasks encouraged students to think critically and problem-solve using familiar symbols and logic embedded within their culture. Thus, this study's findings are consistent

with a growing body of literature confirming the positive relationship between cultural relevance and student engagement in mathematics education.

5.5 Acceptance of the Model by Education Practitioners

The model's acceptance among education practitioners increased moderately to highly positive between the two trials. This shift reflects an increased recognition of the model's value in developing Higher Order Thinking Skills (HOTS) such as analysis, evaluation, and creation (Anderson & Krathwohl, 2001).

Educational practitioners reported that the model aligned with the philosophy and enhanced students' critical reasoning by situating mathematical problems within culturally relevant contexts. These outcomes resonate with cognitive learning theory, which posits that complex thinking skills are better developed when learners are exposed to meaningful, challenging tasks (Bransford, Brown, & Cocking, 2000).

In line with prior findings (Zulkardi, 2002; Saragih & Napitupulu, 2015), this study confirms that culture-based learning environments can effectively promote HOTS development. Practitioners emphasised the model's pedagogical merit and suggested its broader application in teacher training programs focused on culturally responsive education.

Overall, the research findings affirm the practicality and pedagogical value of the model based on the Batak Toba culture in elementary mathematics education. The integration of local cultural contexts not only made mathematical content more accessible and engaging but also aligned with theoretical frameworks advocating for contextualised, constructivist, and culturally responsive learning. Future studies are encouraged to further explore the model's scalability across diverse cultural settings within Indonesia and examine its long-term effects on teaching efficacy and student achievement.

6. Conclusion and Implications

6.1 Conclusion

This study concludes that the Realistic Mathematics Education model integrated with Batak Toba cultural elements demonstrates a high practicality in mathematics instruction for pre-service elementary school teachers. Across four key indicators-model implementation, ease of implementation by lecturers, student engagement, and acceptance by education practitioners—significant improvements were observed between the first and second trials.

The model aligns with the principles of realistic and constructivist learning theories and enhances the contextualization of abstract mathematical concepts through culturally familiar elements such as ulos patterns and traditional house structures. This contextual grounding increases students' engagement, supports critical thinking, and facilitates more profound understanding.

Additionally, the study affirms the importance of professional development in ensuring the model's successful implementation. Targeted training and technical support enable lecturers to integrate local cultural contexts into mathematics instruction effectively. Acceptance from education practitioners further supports the model's pedagogical validity and potential for broader application.

6.2 Implications

For Teacher Education Programs, the findings suggest that integrating local culture into mathematics education can enhance the development of higher-order thinking Skills (HOTS) among pre-service teachers. Teacher education institutions should consider adopting culturally grounded instructional models as part of their curriculum to promote relevant and meaningful learning experiences.

For Mathematics Curriculum Development, curriculum developers are encouraged to incorporate contextual, culture-based content into mathematics learning materials, especially in regions with rich cultural diversity. Doing so will make mathematical concepts more relatable and improve student outcomes.

For policymakers and education practitioners, educational policy should support developing and disseminating localised instructional models such as the Batak Toba model. This includes funding for training programs and resources that empower educators to implement culturally responsive teaching strategies.

Future research is needed to explore the scalability and adaptability of the culturally based model in different ethnic and regional contexts within Indonesia. Longitudinal studies may also be conducted to evaluate the long-term impact of this model on teacher competence and student achievement in mathematics.

Implementing culture-based learning models effectively requires pedagogically competent and culturally literate educators for Professional Development Initiatives. Thus, continuous professional development programs should include modules on cultural integration in teaching, enabling educators to design learning experiences that reflect students' cultural identities.

7. Limitation

This study has several limitations when interpreting the results and applying the findings in future contexts. First, implementing the model based on the Batak Toba culture was conducted at a single higher education institution with a limited number of participants (35 pre-service teachers), which restricts the generalizability of the findings to other educational settings across Indonesia with different cultural characteristics.

Second, the evaluation focused solely on aspects of practicality—namely, model implementation, student engagement, ease of implementation by lecturers, and acceptance by educational practitioners. A more comprehensive analysis of the model's impact on learning outcomes and the development of Higher Order Thinking Skills (HOTS) was not conducted in this study.

Third, due to time and resource constraints, training sessions for lecturers and the development of learning materials were conducted on a limited scale. This may have affected the optimal implementation of the model during the initial trial phase.

Future research should involve broader and more diverse participant groups and employ mixed-method approaches to more comprehensively assess the model's effectiveness, including its long-term impact on pre-service elementary school teachers' pedagogical and professional competencies.

Credit authorship contribution statement

Patri Janson Silaban: The sole author is responsible for conceptualisation, methodology, data collection, formal analysis, writing the original draft, reviewing and editing it, visualisation, and supervising the entire research process.

Declaration of competing interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Ethical Declaration

This study was conducted in accordance with the ethical standards of [Name of Institution or Ethics Committee], and the research protocol was approved by the Institutional Review Board (IRB) or Ethics Committee with approval number [approval number if any]. Informed consent was obtained from all participants before their involvement in the study. The confidentiality and anonymity of the participants were strictly maintained throughout the research process.

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