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# REALISTIC MATHEMATICS EDUCATION GROUNDED IN DELIBERATIVE CULTURE: FOSTERING PROBLEM-SOLVING SKILLS IN PRIMARY EDUCATION

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## ABSTRACT

***This study aims to develop and analyze the implementation of Realistic Mathematics Education (RME) integrated with digital technology and the local culture of deliberation (musyawarah) as a culturally responsive instructional approach to support elementary students' mathematical problem-solving skills. The study employed a Design-Based Research (DBR) methodology conducted through three phases: preliminary design, teaching experiment, and retrospective analysis. The participants consisted of 28 elementary school students at UPTD SD Negeri 4 Bireuen, with the classroom teacher serving as a collaborative partner throughout the research process.Data were collected through classroom observations, recordings of group deliberation discussions, technology-based student worksheets, problem-solving tests, and interviews with both students and the teacher. Data analysis was conducted using qualitative thematic analysis supported by data triangulation. The findings indicate that the integration of RME, digital technology, and deliberative cultural practices can be implemented systematically and meaningfully in classroom instruction. Digital technology functioned as a cognitive tool that supported visualization, exploration of multiple solution strategies, and iterative reflection, while deliberation strengthened social interaction, equitable participation, and the negotiation of mathematical meaning. Students demonstrated diverse informal strategies and gradually progressed toward more formal mathematical representations through guided reinvention and collaborative discussion. Both teachers and students reported positive responses to the learning process, as reflected in increased engagement, confidence, and a stronger focus on problem-solving processes. This study contributes theoretically by enriching RME through culturally responsive and technology-based instructional design principles, and practically by offering a pedagogical framework for meaningful mathematics learning that is relevant to the demands of 21st-century education.***

**KEYWORDS:** Digital Technology, Culturally , RME, Deliberative, Problem Solving

## 1. INTRODUCTION

Mathematics education in the 21st century faces increasingly complex challenges due to the demands for higher-order thinking skills, problem-solving abilities, and sensitivity to students' social and cultural contexts [1];[2];[3]. Mathematics is no longer viewed merely as a set of abstract concepts, but as a human activity that emerges from real-life experiences and social practices[4];[5]. Therefore, culturally responsive teaching has become increasingly relevant to bridge the gap between formal mathematical concepts and students' everyday learning experiences.One approach that consistently emphasizes the connection between mathematics and reality is Realistic Mathematics Education (RME) [6];[7];[8]. RME positions contextual problems as the starting point of learning, encouraging students to construct knowledge through exploration, discussion, and reflection [9];[1]. Research over the past decade has shown that RME positively contributes to students' problem-solving skills, mathematical reasoning, and positive attitudes toward mathematics. However, RME implementation is often generic and has not fully integrated local cultural characteristics as meaningful learning resources [10].

Meanwhile, advancements in educational technology have opened new opportunities to enrich RME implementation. Digital technology enables more authentic, visual, and interactive presentation of contextual problems and facilitates broader student collaboration and reflection [11];[12][13]. Recent studies indicate that the integration of technology in mathematics education can enhance student engagement and support deeper problem-solving processes if applied pedagogically rather than merely as a technical tool [14];[15]; [16]. Nevertheless, many studies still treat technology as separate from students' cultural context, leaving its potential to reinforce local values underutilized.

In the Indonesian context, especially in communities that value collectivism, the culture of deliberation (musyawarah) is deeply rooted in daily life. Musyawarah not only serves as a decision-making mechanism but also functions as a social learning platform that fosters mutual respect, openness, and shared responsibility. Several studies have shown that integrating local cultural values, such as deliberation and consensus (mufakat), into learning can improve student participation and the quality of classroom interactions [17];[4];[2]..However, research that explicitly links deliberative culture with RME, particularly enriched with educational technology, remains relatively limited.

Based on this state of the art, several research gaps can be identified. First, studies on RME over the last decade have focused mainly on its effectiveness in improving cognitive outcomes, while the local cultural dimension often serves merely as contextual background rather than a systematically integrated pedagogical framework. Second, research on educational technology in mathematics tends to emphasize digital innovation and learning outcomes without deeply connecting it to the cultural values present in students' communities. Third, studies that combine RME, educational technology, and deliberative culture as a coherent, culturally responsive approach to problem-solving learning are still scarce, particularly at the primary education level.

These gaps highlight the novelty of this study, which aims to develop and analyze a technology-based RME approach that consciously and systematically integrates deliberative culture as the foundation of learning interactions. This approach is designed not only to enhance students' mathematical problem-solving skills but also to strengthen the social and cultural dimensions of mathematics learning. Thus, learning is oriented not only toward outcomes but also toward meaningful processes aligned with students' cultural values.

The research problem stems from the fact that students' problem-solving abilities remain relatively low, as indicated by difficulties in understanding contextual problems, formulating solution strategies, and communicating their mathematical thinking. Additionally, classroom mathematics instruction is still dominated by one-way interactions and does not fully facilitate equitable collaborative discussions. Hypothetically, it can be assumed that mathematics learning that is not culturally responsive and insufficiently supported by meaningful technology contributes to the low quality of students' problem-solving processes and outcomes.

As a solution, this study proposes a technology- and deliberation-based Realistic Mathematics Education approach. Technology serves as a medium to present realistic problems relevant to students' lives and to support visualization and solution exploration. Deliberative culture is integrated into each RME phase, particularly during strategy exploration and discussion, so that students become accustomed to expressing opinions, listening to others, and reaching consensus through dialogic processes. This approach is expected to create an inclusive, collaborative, and meaningful learning environment.

The purpose of this study is to describe and analyze the implementation of technology- and deliberation-based RME as a culturally responsive approach to problem-solving learning. Specifically, it aims to examine how this approach affects students' mathematical problem-solving processes, the quality of learning interactions, and the responses of students and teachers to learning that integrates technology and local cultural values. The study is expected to contribute theoretically to the development of contextually and culturally responsive RME research and practically to teachers' design of mathematics learning that is relevant to students' social and cultural contexts.

## 2. LITERATURE REVIEW

### *2.1. The Role of Digital Technology in Supporting the Principles of Realistic Mathematics Education*

Digital technology is increasingly regarded as a crucial element in the development of meaningful mathematics learning, particularly within the framework of Realistic Mathematics Education (RME). The literature indicates that technology has significant potential to reinforce the core principles of RME by presenting more authentic, context-rich, and easily understandable real-world problems. Through digital visualization and representation, complex real-life situations can be simplified without losing their mathematical meaning, helping students build connections between everyday experiences and formal concepts [18].

In the context of problem-solving, technology allows students to explore strategies more flexibly and in greater depth. Digital environments provide space for students to experiment with multiple solution approaches, test hypotheses, and revise strategies based on immediate feedback. This process aligns with RME's emphasis on students' active role in knowledge construction through experimentation and reflection. Studies have shown that using technology as an exploratory tool can enhance the quality of mathematical reasoning and encourage students to focus on the problem-solving process rather than merely obtaining final answers [19];[20].

Technology also plays a clear role in supporting the principle of guided reinvention. It functions as a cognitive tool that helps students develop informal strategies and initial models before transitioning to more formal mathematical representations. Through dynamic simulations and virtual object manipulation, students can observe patterns, relationships, and changes visually, facilitating the transition from intuitive understanding to conceptual comprehension. Thus, technology serves not merely as an information delivery medium but as a means to facilitate students' guided reinvention of mathematical concepts [21];[22].

However, the literature emphasizes that the effectiveness of technology in the RME framework depends heavily on the accompanying pedagogical design. Technology used without consideration of RME principles risks shifting learning toward procedural tasks or passive visualization. Therefore, technology integration should be deliberately designed to support exploration, discussion, and reflection in problem-solving. These findings affirm that in RME, technology must be positioned as a cognitive tool that strengthens meaningful learning processes rather than as an end goal of educational innovation [23];[9]

### *2.2. Technology as a Facilitator of Exploration and Problem-Solving Strategies*

Digital technology has been shown to expand students' exploratory space in mathematics learning, especially in problem-solving contexts. Various studies indicate that digital environments provide opportunities for students to interact directly with mathematical objects, manipulate variables, and observe changes in real-time. This condition allows students to gain a deeper understanding of problem structures and to develop diverse solution strategies compared to conventional learning, which often restricts exploration to a single procedural approach [24]

In technology-based learning environments, students are given room to try multiple problem-solving approaches without pressure to arrive at the correct answer immediately. Mistakes are treated as part of the learning process because technology allows repeated revision and refinement of solutions. This iterative process aligns with RME characteristics, emphasizing thinking, reflection, and the development of informal strategies before reaching formal solutions. Therefore, technology supports learning processes oriented toward understanding rather than merely obtaining final results.

Technology also assists students in developing and comparing different problem-solving strategies. Through digital visualization and representation, students can see the consequences of each strategy, allowing them to evaluate the effectiveness and efficiency of the approaches chosen. Research shows that this experience contributes to increased cognitive flexibility and mathematical reasoning skills, as students are not confined to a single procedural method [25];[26]

However, the literature emphasizes that technology's role as a facilitator of exploration is optimized only when supported by appropriate instructional design. Without clear pedagogical guidance, technology use may lead students into unguided or unfocused exploration. Therefore, within the RME framework, teachers play a crucial role in facilitating discussions, reflections, and synthesis of students' explorations to ensure that technology functions as a cognitive tool supporting meaningful problem-solving strategy development.

### *2.3. Technology and Social Interaction in Collaborative Mathematics Learning*

Recent literature emphasizes that digital technology plays a vital role in facilitating social interaction and collaboration among students in mathematics learning. Various digital platforms and collaborative applications enable students to communicate, share ideas, and construct shared understanding systematically. In mathematics learning, technology-mediated social interaction provides space for students to express their thinking through visual, symbolic, and verbal representations, enriching the problem-solving process [27];[28];[29].

In the context of RME, social interaction is an essential component that supports the negotiation of mathematical meaning. Technology extends discussion space beyond the constraints of classroom time and physical space, allowing more equitable student participation. Through interactive media and collaborative digital environments, students can present strategies, respond to peers' ideas, and revise their understanding based on feedback received. This process aligns with RME's emphasis on discussion and reflection as part of meaningful learning.

Technology also contributes to improving collaboration quality in mathematics problem-solving. Features such as online group work, digital whiteboards, and shared annotation tools allow students to work collectively in analyzing problems and developing solutions. Studies indicate that technology-based collaboration can enhance the quality of mathematical argumentation and deepen conceptual understanding, as students engage in explaining and defending their ideas [30];[31].

Nevertheless, the literature cautions that technology-mediated social interaction requires careful pedagogical management. Without clear structure, technology-based discussions may become unfocused and fail to support learning objectives. Therefore, within the RME framework, teachers remain crucial in designing collaborative activities, facilitating discussions, and guiding the negotiation of mathematical meaning to ensure that technology effectively strengthens social interaction and meaningful problem-solving.

### *2.4. Integration of Technology and Culturally Responsive Approaches in Mathematics Learning*

Culturally responsive teaching emphasizes linking learning processes to students' social contexts, values, and lived cultural practices. In mathematics education, this approach aims to make learning more meaningful by integrating students' cultural experiences as an integral part of the learning process. Literature shows that when learning aligns with students' cultural identities, engagement, motivation, and conceptual understanding tend to increase [32];[33];[34]

With the development of educational technology, opportunities arise to strengthen culturally responsive approaches through digital media. Technology enables teachers to present contextual situations reflecting local social and cultural practices through visualizations, simulations, or interactive environments. Thus, technology functions not only as a technical tool but also as a medium for cultural representation, helping students connect mathematical concepts to social realities they recognize. Research indicates that integrating technology and cultural context can enrich learning experiences and deepen conceptual understanding.

In mathematics learning, culturally contextualized technology allows students to explore problems relevant to their daily life and community practices. Through familiar contexts, students can more easily comprehend problem structures and develop meaningful solution strategies. This aligns with [35] perspective, which emphasizes that culturally responsive teaching should encourage students to use their cultural knowledge as an intellectual resource in the learning process, rather than merely as illustrative examples.

Despite the potential of integrating technology and culturally responsive approaches, the literature notes limitations in current practice and research. Most studies still separate technological innovation from cultural values, focusing primarily on digital tool effectiveness or cognitive outcomes. Consequently, technology is often applied neutrally and universally, without considering students' diverse cultural backgrounds. This limits the potential of technology as a means to reinforce cultural identity and meaningful learning.

Based on this review, it can be concluded that integrating technology and culturally responsive approaches requires deliberate and contextual pedagogical design. Technology should be positioned as a medium that enables representation of students' socio-cultural practices and supports meaningful learning interactions. This approach ensures that mathematics learning is oriented not only toward concept mastery but also toward developing understanding relevant to students' lives and cultures, opening the way for more inclusive and equitable learning.

### *2.5. Limitations of Previous Research and Opportunities for Technology Integration in RME*

Although various studies have demonstrated the positive impact of technology on mathematics learning, most research still focuses on technical aspects of technology use and students' cognitive outcomes. Many studies assess technology effectiveness based on improved learning results or delivery efficiency, without deeply linking it to the underlying pedagogical approach. Consequently, technology is often positioned as an additional tool rather than as an integral part of instructional design that supports students' mathematical thinking and meaning-making processes [36].

In the context of RME, research limitations are evident in the scarcity of studies that conceptually integrate technology with RME principles. Some studies employ technology in problem-based learning but do not explicitly connect it with guided reinvention, didactical phenomenology, or self-developed models. Without alignment with these principles, technology use risks turning RME instruction into procedural tasks or mere visualization, reducing its potential to support meaningful problem-solving [37].

Another notable limitation in the literature is the lack of attention to cultural dimensions in integrating technology and RME. Most studies still use general or universal contexts without considering students' local social practices and cultural values as learning resources. As a result, learning tends to be less responsive to students' socio-cultural backgrounds and does not fully leverage technology as a medium for cultural representation [38].

These gaps highlight the novelty potential of developing mathematics learning approaches that combine technology, RME, and local cultural values into a coherent pedagogical framework. Such integration can not only enhance students' mathematical problem-solving abilities but also enrich learning interactions and conceptual understanding through culturally relevant contexts. Therefore, research examining technology integration in culturally grounded RME contributes both to the development of instructional practices and to extending the theoretical framework of RME toward a more contextualized and culturally responsive approach.

## 3. RESEARCH METHODOLOGY

### *3.1. Research Design*

This study employed a Design-Based Research (DBR) approach aimed at developing, implementing, and analyzing mathematics learning based on Realistic Mathematics Education (RME), enriched with digital technology and the local deliberation (musyawarah) culture to enhance students' problem-solving skills. The DBR approach was chosen because it allows in-depth investigation of learning processes in real-world contexts while simultaneously generating contextually grounded and practical design principles. Through this approach, the study focuses not only on learning outcomes but also on the processes, interactions, and dynamics occurring during the implementation of the learning design.

### *3.2. Research Phases*

The study was conducted through the three main phases of DBR: preliminary design, teaching experiment, and retrospective analysis. Preliminary Design Phase: In this phase, the researchers conducted a curriculum analysis and needs assessment of primary school mathematics learning to identify competencies, materials, and student characteristics relevant to problem-solving learning. A comprehensive literature review was also undertaken on Realistic Mathematics Education, the integration of technology in mathematics learning, and culturally responsive teaching approaches. Based on this analysis, the researchers designed learning scenarios, supporting digital media, and musyawarah-based discussion patterns aligned with RME principles.

Teaching Experiment Phase: This phase involved the implementation of the developed learning design in a real classroom setting. Contextual problems were presented as the starting point of learning activities. Students worked in small groups, applying musyawarah principles to explore problem-solving strategies. Digital technology was used to facilitate problem visualization, solution exploration, and collaborative discussion. The teacher acted as a facilitator, guiding student discussions and reflections throughout the learning process.

Retrospective Analysis Phase: In this phase, all data collected during the teaching experiment were systematically analyzed. The analysis focused on students' problem-solving processes, the quality of deliberation-based interactions, and the effectiveness of the implemented learning design. The results were used to reflect on the strengths and limitations of the design and to formulate design principles that can guide the development of technology- and culture-based RME learning in similar contexts.

### *3.3. Research Subjects and Context*

The study involved 28 primary school students from a single class at SD Negeri 4 Bireuen. Participants were purposively selected to ensure full engagement in the implemented learning design. The classroom teacher collaborated as a co-researcher in planning and implementing the learning activities. The study was conducted in a local cultural context where musyawarah is still highly valued, providing a relevant setting to integrate this cultural practice into mathematics learning.

### *3.4. Data Collection Techniques*

Data were collected using multiple techniques to provide a comprehensive understanding of both the learning process and outcomes. Observations were conducted to record student and teacher activities, particularly interactions during musyawarah-based discussions. Group discussion recordings were used to analyze communication processes and the negotiation of mathematical meaning among students. Student worksheets developed using digital tools were collected as learning artifacts reflecting problem-solving strategies and representations. Additionally, problem-solving tests were administered to assess students' mathematical problem-solving abilities, and interviews with students and the teacher were conducted to obtain supporting data on their experiences and responses to the learning process.

### *3.5. Data Analysis Techniques*

Data were analyzed qualitatively using thematic analysis, focusing on learning processes, social interaction patterns, and musyawarah practices in problem-solving. Problem-solving analysis examined strategies employed by students, emerging mathematical representations, and reflective processes throughout learning. To enhance the validity of findings, data triangulation was conducted by comparing observations, learning artifacts, and interview data, yielding a comprehensive and in-depth understanding of the implementation of the developed learning design.

## 4. RESULTS

### *4.1. Implementation of RME Learning Integrated with Technology and Deliberation Culture*

The findings indicate that mathematics learning based on Realistic Mathematics Education (RME), enriched with digital technology and musyawarah (deliberation) culture, can be systematically and contextually implemented in the classroom. The learning process began with presenting realistic problems relevant to students' experiences, delivered through digital media to facilitate visualization and contextual understanding. These problems then served as triggers for group discussions and exploration of problem-solving strategies in musyawarah-based groups.

During the learning process, technology functioned as a cognitive tool supporting students' exploration of ideas and mathematical representations. Students used digital media to model problem situations, test various solution strategies, and discuss the outcomes. The deliberation culture was reflected in the group interaction patterns, where students took turns sharing opinions, responding to peers' ideas, and collectively reaching agreement on the chosen strategies.

***Table 1: Analysis of RME Principles Implementation with Technology and Musyawarah.***

| Learning Aspect | Implementation Indicators | Field Findings | Analytical Meaning |
|---|---|---|---|
| Realistic problems | Problems linked to students' daily experiences | Problems presented in students' life contexts and visualized digitally | Contextual problems serve as starting points for mathematical thinking consistent with RME principles |
| Guided reinvention | Students construct strategies before formal concepts | Students developed informal strategies through group discussions | Guided reinvention occurs through exploration and dialogue |
| Didactical phenomenology | Contextual phenomena represent mathematical concepts | Digital media helps connect context to mathematical concepts | Technology strengthens the bridge from context to abstraction |
| Self-developed models | Students create their own models or representations | Students produced sketches, tables, and digital representations | Student-generated models provide a foundation for formal understanding |
| Musyawarah culture | Discussions are participatory and equitable | Students took turns sharing opinions and reaching consensus | Musyawarah reinforces social interaction and mathematical meaning negotiation |

***Table 2: Role of Technology and Musyawarah in Problem-Solving Processes.***

| Analytical Component | Student Activities | Data Evidence | Impact on Problem-Solving |
|---|---|---|---|
| Technology as cognitive tool | Problem visualization and solution simulation | Digital artifacts and classroom observation | Helps students understand problem structures |
| Strategy exploration | Testing various solution approaches | Technology-based worksheets | Increases thinking flexibility |
| Deliberation discussion | Idea exchange and argumentation | Group discussion recordings | Deepens mathematical reasoning |
| Meaning negotiation | Agreeing on optimal strategies | Observation notes and interviews | Encourages reflection and solution justification |
| Decision-making | Group consensus on solutions | Final group discussion outcomes | Demonstrates cognitive-social integration |

### *4.2. Students' Problem-Solving Process in a Culturally Responsive Learning Environment*

Analysis of students' problem-solving processes revealed diverse strategy use, often not immediately dependent on formal procedures. Initially, students proposed informal strategies based on contextual understanding, such as sketches, simple tables, or verbal reasoning. Through musyawarah discussions and digital visualization support, these strategies were refined and guided toward more formal mathematical representations.

Social interaction in musyawarah groups played a crucial role in deepening students' understanding. Students not only defended their own ideas but also adapted and revised strategies based on peer input. This process of negotiating mathematical meaning reflects a collaborative and reflective learning environment, aligning with RME principles that emphasize knowledge construction through social interaction.

***Table 3: Analysis of Stages in Students' Problem-Solving Process.***

| Problem-Solving Stage | Student Behavioral Indicators | Emergent Strategies | Analytical Meaning |
|---|---|---|---|
| Understanding the problem | Identifying contextual information | Verbal reasoning and initial discussion | Students connect problems to real-life experiences |
| Strategy design | Proposing multiple solution methods | Sketches, simple tables, estimations | Informal strategies serve as starting points for mathematical thinking |
| Strategy execution | Testing and revising solutions | Visual representations and digital models | Technology supports exploration and strategy correction |
| Result interpretation | Explaining solutions to the group | Oral and symbolic argumentation | Reflection reinforces conceptual understanding |
| Consensus building | Reaching group agreement | Joint decision-making | Musyawarah encourages consensus based on mathematical reasoning |

***Table 4: Role of Musyawarah and Technology in Negotiating Mathematical Meaning.***

| Analytical Aspect | Interaction Form | Data Source | Impact on Understanding |
|---|---|---|---|
| Idea exchange | Turn-taking to express opinions | Discussion recordings | Enriches alternative strategies |
| Feedback | Responding to peers' ideas | Classroom observation | Promotes clarification and justification |
| Strategy revision | Collaborative solution improvement | Digital worksheets | Strengthens collective reflection |
| Meaning negotiation | Aligning conceptual understanding | Student interviews | Co-constructed mathematical meaning |
| Group reflection | Evaluating processes and outcomes | Reflection notes | Learning is collaborative and meaningful |

### *4.3. Role of Technology in Supporting Problem-Solving Exploration and Discussion*

Observations and analysis of learning artifacts revealed that digital technology facilitated deeper problem exploration. Visualization and manipulation of mathematical objects enabled students to understand concept relationships and evaluate the effectiveness of applied strategies. Technology also provided feedback that encouraged iterative solution revisions, making the problem-solving process more reflective and meaningful.

Moreover, technology enhanced the quality of musyawarah group discussions. Digital media served as a focal point, allowing students to explain ideas, compare strategies, and reach agreements more efficiently. Student participation became more balanced, including those previously less active in conventional learning settings.

**Table 5: Analysis of Technology's Role in Problem-Solving Exploration.**

| Analytical Aspect | Technology Utilization | Empirical Evidence | Contribution to Problem-Solving |
|---|---|---|---|
| Problem visualization | Digital representation of context | Media artifacts and observation | Helps students understand problem structure and relationships |
| Object manipulation | Variable adjustment and simulation | Digital worksheets | Enables exploration of multiple solution possibilities |
| Feedback | Immediate response from digital tools | Student process notes | Encourages strategy evaluation and revision |
| Iterative exploration | Repeated solution testing | Digital activity traces | Promotes reflective problem-solving |
| Concept construction | Transition from context to symbols | Student work products | Strengthens conceptual understanding |

**Table 6: Analysis of Technology's Role in Musyawarah Group Discussions.**

| Interaction Aspect | Role of Digital Media | Data Source | Impact on Discussion |
|---|---|---|---|
| Discussion focus | Media as shared attention center | Classroom observation | Discussion becomes more structured and systematic |
| Idea explanation | Visualized solutions and steps | Discussion recordings | Student ideas are more easily understood |
| Strategy comparison | Display of multiple solutions | Group artifacts | Encourages mathematical argumentation |
| Student participation | Equal access and interaction | Participation observation | Increases engagement of previously passive students |
| Decision-making | Consensus based on visual representation | Group discussion outcomes | Musyawarah becomes more objective and inclusive |

### 4.4. Students' and Teacher's Responses to Learning

Interview data indicated that students responded positively to RME learning integrated with technology and musyawarah culture. Students reported that learning was more engaging and easier to understand because they could discuss with peers and use technology to visualize problems. They also felt more confident expressing opinions and participating in problem-solving activities.

Teachers observed that integrating musyawarah culture facilitated classroom discussion management and encouraged more equitable student engagement. Teachers noted changes in students' attitudes, including increased cooperation, openness to others' ideas, and greater focus on problem-solving processes rather than merely outcomes. This suggests that the developed approach positively impacted not only cognitive but also social and affective dimensions of learning.

**Table 7: Students' Responses to RME Learning with Technology and Musyawarah.**

| Response Aspect | Student Statement Indicators | Data Source | Analytical Meaning |
|---|---|---|---|
| Learning interest | Learning felt engaging and enjoyable | Student interviews | RME and technology enhance motivation |
| Concept understanding | Problems easier to comprehend | Interviews and artifacts | Context and visualization strengthen understanding |
| Self-confidence | Willingness to express opinions | Discussion observations | Musyawarah creates a safe space for sharing |
| Participation | Active involvement in group discussions | Discussion recordings | Student engagement becomes more balanced |
| Reflective attitude | Willingness to revise and evaluate solutions | Student worksheets | Focus on problem-solving process |

**Table 8: Teacher's Responses to Learning Implementation**

| Teacher Assessment Aspect | Key Findings | Data Evidence | Pedagogical Implications |
|---|---|---|---|
| Classroom management | Discussions more structured and conducive | Teacher interviews | Musyawarah supports class management |
| Student engagement | Participation more balanced | Classroom observation | Technology helps reach all students |
| Student attitudes | More cooperative and open | Teacher reflection notes | Learning impacts social-affective aspects |
| Learning focus | Emphasis on process rather than outcome | Teacher interviews | Aligns with RME principles |
| Implementation feasibility | Easily applied and adaptive | Teacher interviews | Potential for replication in other contexts |

### 4.5. Emergent Design Principles

Based on the retrospective analysis, several learning design principles were formulated. First, realistic problems presented through technology should be rooted in students' socio-cultural contexts to trigger meaningful engagement and understanding. Second, technology should function as a cognitive tool supporting exploration and reflection, not merely as a presentation medium. Third, musyawarah culture should be explicitly integrated into all stages of RME learning to strengthen social interaction and negotiation of mathematical meaning. These principles serve as the foundation for developing culturally responsive, problem-solving-oriented mathematics learning.

*Table 9: Design Principles of RME Learning with Technology and Musyawarah.*

| Design Principle | Description | Empirical Basis | Learning Implications |
|---|---|---|---|
| Culturally contextualized | Realistic problems rooted in students' socio-cultural context | Observations and student artifacts | Enhances engagement and learning meaningfulness |
| Technology as cognitive tool | Supports exploration and reflection | Digital activity traces | Strengthens mathematical thinking process |
| Musyawarah integration | Structured discussions based on deliberation values | Discussion recordings | Reinforces social interaction and meaning negotiation |
| Guided reinvention | Students construct concepts through informal strategies | Student process analysis | Natural transition from informal to formal understanding |
| Continuous reflection | Iterative evaluation of strategies and solutions | Student reflection worksheets | Promotes deeper, meaningful learning |

*Table 10: Alignment of Design Principles with Theoretical Framework.*

| Design Principle | Theoretical Framework | Evidence of Alignment | Theoretical Contribution |
|---|---|---|---|
| Contextual problems | Realistic Mathematics Education | Students' informal strategies | Strengthens the role of context in RME |
| Cognitive technology | Cognitive Tools Theory | Iterative exploration | Repositions technology in RME |
| Musyawarah | Sociocultural Learning Theory | Meaning negotiation | Integrates local cultural values |
| Social interaction | Social Constructivism | Collaborative discussions | Promotes meaningful collaborative learning |
| Reflection | Metacognition | Strategy revision | Enhances awareness of thinking processes |

## 5. DISCUSSION

The findings of this study indicate that mathematics learning based on Realistic Mathematics Education (RME), enriched with digital technology and musyawarah (deliberation) culture, can be implemented systematically and contextually in primary schools. These results reinforce the view that meaningful mathematics learning should originate from students' real-life experiences and be developed through social activities that enable active knowledge construction. Within the RME framework, realistic problems function as starting points for mathematical thinking, while guided reinvention allows students to gradually build conceptual understanding from informal strategies toward formal representations. These findings are consistent with Gravemeijer (2014) and Van den Heuvel-Panhuizen (2020), who emphasize that RME's strength lies in connecting students' life contexts with mathematical structures through progressive modeling and reflection.

The integration of digital technology in RME learning in this study further strengthened the function of realistic problems and the exploration of problem-solving strategies. Technology did not merely serve as a visualization medium but acted as a cognitive tool, enabling students to manipulate mathematical objects, test multiple solution possibilities, and iteratively revise their strategies. This finding aligns with [39], who argued that technology has a significant impact on mathematics learning when it supports students' cognitive activities rather than merely conveying information. With technological support, students can better understand the relationships between concepts, evaluate the effectiveness of strategies, and develop more meaningful mathematical representations. This demonstrates that technology plays a critical role in reinforcing guided reinvention and self-developed models in RME.

The observed problem-solving processes revealed that students tended to employ diverse strategies rather than immediately relying on formal procedures. Initially, students proposed informal ideas derived from their contextual understanding of the problem, such as verbal reasoning, sketches, or simple tables. These strategies were then refined and developed through group discussions and digital visualization support, eventually leading to more formal mathematical representations. These findings align with RME's emphasis on students' reasoning and thinking processes as the foundation for conceptual understanding [40] and are consistent with [41] who highlighted that problem-solving skills develop when students are given space to explore multiple strategies and reflect on their thinking processes.

Social interaction within musyawarah groups played a pivotal role in deepening students' mathematical understanding. Through deliberation, students not only defended their own ideas but also listened to, responded to, and revised strategies based on peer input. The process of negotiating mathematical meaning indicates that learning occurred collaboratively and reflectively. This finding reinforces the social constructivist perspective, which views learning as a socially mediated process through interaction and language [42]. Within this context, musyawarah functions as a cultural framework that regulates the quality of social interaction, promotes equitable participation, and instills mutual respect in mathematical discussions.

The presence of technology in musyawarah discussions further enhanced the quality of interactions and student engagement. Digital media served as a shared focus point, helping students explain ideas, compare strategies, and reach consensus more objectively. This finding is consistent with [4];[43];[44], who demonstrated that collaborative technology can expand interaction spaces and increase student participation in mathematics learning. Notably, this study shows that technology can engage students who were previously less active in conventional classrooms, resulting in more inclusive and balanced discussions. These findings suggest that integrating technology with musyawarah culture contributes to creating a learning environment responsive to students' needs and characteristics.

Students' positive responses to RME learning integrated with technology and musyawarah indicate that this approach enhances motivation, confidence, and engagement in problem-solving. Students felt more comfortable expressing opinions and actively participating in group discussions. This finding aligns with [45], who emphasized that culturally responsive learning can create safe, inclusive, and empowering learning spaces. By leveraging culturally familiar values, learning becomes not only cognitively relevant but also socially and emotionally meaningful.

From the teachers' perspective, integrating musyawarah culture facilitated classroom discussion management and promoted more equitable student participation. Teachers observed changes in students' attitudes, including increased cooperation, openness to others' ideas, and greater focus on problem-solving processes. These findings support [46];[47], who highlighted that structured mathematical discussions help teachers manage classroom interactions effectively while deepening students' understanding. Therefore, the approach developed in this study impacts not only the cognitive but also the social and affective dimensions of mathematics learning.

As a Design-Based Research study, the primary contribution of this research lies in formulating design principles derived from retrospective analysis. These principles reflect a synthesis of empirical findings and theoretical frameworks, including RME, cognitive tools theory, and sociocultural learning theory. The study extends the RME literature by demonstrating that integrating technology and local cultural values can form a coherent pedagogical approach. Unlike previous studies, which often treated technological innovation and culturally responsive approaches separately, this research shows that both elements can mutually reinforce one another to support meaningful problem-solving learning.

Overall, the discussion indicates that mathematics learning grounded in RME, technology, and musyawarah culture holds substantial potential to holistically develop students' problem-solving abilities. Learning not only promotes mastery of mathematical concepts but also cultivates reflective thinking, communication skills, and positive social attitudes. Consequently, this study offers both theoretical and practical contributions to the development of culturally responsive mathematics education relevant to 21st-century educational demands.

## 6. CONCLUSION

This study concludes that mathematics learning based on Realistic Mathematics Education (RME), integrated with digital technology and musyawarah (deliberation) culture, can foster a meaningful, contextual, and student-responsive learning process in primary education. The integration of realistic problems, the use of technology as a cognitive tool, and the implementation of musyawarah in group discussions were shown to support the development of problem-solving skills through strategy exploration, negotiation of mathematical meaning, and collaborative reflection. The learning process not only strengthens students' conceptual understanding and mathematical reasoning but also promotes active engagement, cooperative attitudes, and confidence in mathematical communication. Consequently, this study affirms that the synthesis of RME, technology, and local cultural values can form a coherent and effective pedagogical framework that is highly relevant for supporting 21st-century mathematics education.

### *6.1. Ethical issue*

This study was conducted in strict accordance with the principles of educational research ethics.

Prior to the implementation of the study, official permission was obtained from the school authorities, and the objectives, procedures, and potential benefits of the research were communicated to the principal and classroom teachers. Student participation was voluntary and contingent upon the consent of both the teacher and the students' parents or guardians, given that the research subjects were primary school children. All collected data, including observations, interviews, documentation, and learning artifacts, were treated with strict confidentiality, with no personal identifiers of students or teachers disclosed. The data were used solely for academic purposes and scientific reporting. Furthermore, the learning activities were designed to avoid any psychological or academic risks to the students while remaining aligned with the existing curriculum. Thus, the study upheld the ethical principles of respect for participants' rights, fairness, safety, and academic responsibility.

## 7. DATA AVAILABILITY STATEMENT

The manuscript contains all the data. However, more data will be available upon request from the authors

## 8. CONFLICT OF INTEREST

The author declares no potential conflict of interest.

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