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A Realistic Mathematics Education (RME)-Based Mathematics Textbook to Improve Students' Conceptual Understanding and Critical Thinking Skills

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ABSTRACT

Purpose – This study aims to develop a Grade V mathematics textbook based on Realistic Mathematics Education (RME) to support students' mathematical conceptual understanding and critical thinking skills.

Methodology – This research employed a Research and Development (R&D) approach using the 4D development model: Define, Design, Develop, and Disseminate. The implementation involved 23 fifth-grade students and one teacher at SD Negeri 26/IV Jambi, Indonesia. Data were collected through observations, interviews, validation questionnaires, teacher and student response questionnaires, conceptual understanding and critical thinking tests, critical-thinking observation sheets, and documentation. Data analysis included validity, practicality, dissemination, and N-Gain analysis of students' conceptual understanding and critical thinking.

Findings – The results showed that the developed RME-based mathematics textbook was very valid and practical. Validation scores reached 100% for design, 93.33% for content, and 93.85% for language, all of which were categorized as very valid. Practicality scores were 92% from the teacher, 90% from students in the limited trial, and 92% in the larger-group trial, all categorized as very practical. Students' conceptual understanding improved, with N-Gain increasing from 0.42 in Cycle I to 0.50 in Cycle II, while critical thinking increased from 0.33 to 0.43, both in the moderate category. The dissemination response reached 95.88%, indicating very high teacher acceptance.

Contribution – This study contributes an RME-based mathematics textbook that integrates contextual problems, exploration, discussion, mathematical reasoning, and concept formalization into a structured learning resource. The developed textbook provides a viable alternative for supporting conceptual understanding and critical thinking in Grade V mathematics.

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INTRODUCTION

Elementary education plays an important role in developing students' cognitive, social, and character foundations (Sihombing et al., 2024). At this level, learning is expected to provide meaningful experiences that support students' intellectual development, character formation, and acquisition of skills relevant to their daily lives (Darling-hammond et al., 2020). Therefore, the learning process needs to be designed in line with students' developmental characteristics, learning needs, and the demands of contemporary education. The implementation of the Merdeka Curriculum provides opportunities for teachers to select and develop teaching materials that are relevant to students' needs while emphasizing deeper conceptual understanding and competency development.

Mathematics is an essential subject in achieving these goals because it develops students' logical, systematic, analytical, and creative thinking (Karim & Wiranegara, 2025). At the elementary level, mathematics is not limited to computational skills but also supports problem-solving, reasoning, and conceptual understanding. Mathematical conceptual understanding enables students to connect, explain, interpret, and apply mathematical ideas rather than merely memorize formulas or procedures (Ncube et al., 2024). In addition, critical thinking enables students to analyze information, evaluate solution strategies, draw inferences, and provide logical explanations (Mastuti & Sehuwaky, 2022). Therefore, conceptual understanding and critical thinking are important competencies in meaningful mathematics learning.

However, these competencies have not been optimally developed in classroom practice. An initial observation conducted on October 30, 2025, at SD Negeri 26/IV Jambi found that mathematics instruction remained predominantly conventional and teacher-centered. Students mainly received explanations rather than actively constructing mathematical concepts or exploring alternative problem-solving strategies. One contributing factor was the use of teaching materials. The textbook, published in 2021, was predominantly procedural and provided limited opportunities for exploration, real-life contextualization, and independent concept construction. Consequently, it did not fully support the characteristics of the Merdeka Curriculum or the development of conceptual understanding and critical thinking.

This condition was corroborated by an interview with the Grade V teacher, Bapak Satrio Apdianto, S.Pd., on October 30, 2025, who reported that the existing textbook was insufficiently contextual and did not adequately facilitate students' deep conceptual understanding. Students also demonstrated diverse learning abilities, indicating the need for teaching materials that accommodate different characteristics while encouraging exploration and reasoning. Furthermore, an initial test administered to 23 students on April 1, 2026, showed that 7 students scored 0, 9 scored 20, 6 scored 40, and only 1 scored 60; no student scored 80 or 100. These findings indicate that students' mathematical conceptual understanding remained low and their critical thinking skills had not developed optimally.

These conditions reveal a gap between the learning demands of the Merdeka Curriculum and actual classroom practices. In particular, the Grade V mathematics learning outcomes within Phase C emphasize students' ability to understand and apply mathematical concepts, use mathematical representations, solve contextual problems, and communicate their reasoning in relevant mathematical domains (Koskinen, 2022). Such expectations require learning experiences that go beyond procedural exercises and encourage students to connect mathematical ideas with situations they can understand. This orientation is consistent with the principles of *Realistic Mathematics Education* (RME), which views mathematics as a human activity and emphasizes the process of mathematization. RME begins with meaningful contextual problems and guides students to explore situations, develop informal strategies, construct models, discuss different approaches, and gradually formalize mathematical concepts. Through this process, students can move from concrete or familiar situations toward more abstract representations and formal mathematical reasoning. The alignment between RME and the Merdeka Curriculum is therefore substantive: both support meaningful learning, conceptual development, contextual problem-solving, and active student participation. Moreover, RME activities can create opportunities for students to explain their thinking, compare strategies, justify conclusions, and reflect on solutions, which are relevant to the development of critical thinking.

Integrating RME into a mathematics textbook is therefore relevant because it can address specific limitations in existing teaching materials and translate curriculum expectations into structured learning activities. Rather than merely presenting definitions, formulas, worked examples, and routine exercises, an RME-based textbook can organize learning around contextual problems, student-generated strategies, visual or symbolic models, mathematical discussions, and reflection activities. For example, students can begin with familiar situations, represent the information using drawings, objects, tables, or diagrams, and gradually develop more formal mathematical procedures. These learning sequences can help students connect prior knowledge with new concepts, understand why a procedure works, and apply mathematical ideas to unfamiliar problems. In addition, questions that require students to explain their strategies, compare possible solutions, identify errors, and justify conclusions can provide more explicit support for critical thinking. Previous studies have shown that RME can support conceptual understanding through contextual problems. (Wahyu et al., 2024). Contextual learning can promote critical thinking through exploration and discussion (Thamrin et al., 2024). Setioningsih & Wardani, (2025) Also, studies have found that contextual teaching materials can facilitate deeper mathematical understanding than materials focused primarily on procedural problem-solving. These findings provide a rationale for developing teaching materials that integrate contextual learning with opportunities for mathematical reasoning.

Nevertheless, the findings of previous studies do not eliminate the need to examine the design and completeness of RME-based textbooks in relation to the specific learning needs of Grade V students. In particular, the presence of contextual problems alone does not necessarily ensure that a textbook systematically guides students from informal strategies to mathematical models, formal concepts, and reflective reasoning. Likewise, teaching materials that emphasize conceptual understanding may not explicitly incorporate tasks requiring students to analyze information, compare strategies, evaluate solutions, and justify conclusions (Alsaleh, 2020). The present study addresses this design gap by focusing on a textbook that integrates these elements within a coherent learning sequence. Furthermore, the need for development is grounded in the documented conditions at SD Negeri 26/IV Jambi, where the existing textbook was reported to be insufficiently contextualized, and the initial assessment indicated low achievement in mathematics. Rather than assuming that all existing RME textbooks share the same limitations, this study identifies the specific instructional needs of the target context. It develops a product in response to those needs. Accordingly, the research focuses not only on the use of RME as a classroom approach but also on translating its principles into a structured, curriculum-relevant textbook that simultaneously supports mathematical conceptual understanding and critical thinking.

The novelty of this study lies in the development of an RME-based mathematics textbook for Grade V elementary students that systematically integrates real-life contexts, exploratory activities, mathematical representations, and reasoning tasks to support both mathematical conceptual understanding and critical thinking. Unlike a textbook that primarily presents procedures and routine exercises, the developed product is designed to guide students through a progression from contextual situations and informal strategies toward mathematical models, formal concepts, and reflective problem-solving. Its development is also informed by the learning needs identified at the research site and the competency-oriented direction of the Merdeka Curriculum for Phase C. The textbook is developed using the 4D model (*Define, Design, Develop, Disseminate*) proposed by Thiagarajan, Semmel, and Semmel (1974), providing a systematic process from needs analysis and product design to validation, implementation, and dissemination. Based on these considerations, this study aims to develop an RME-based mathematics textbook for Grade V elementary students and examine its feasibility and potential to improve students' mathematical conceptual understanding and critical thinking skills.

METHODOLOGY

Research Design

This study employed a Research and Development (R&D) approach using the 4D development model proposed by Thiagarajan, S., D. Semmel, (1974)consisting of four stages: Define, Design, Develop, and Disseminate. The 4D model was selected because it provides a systematic procedure for developing educational products through needs identification, product design, expert validation, product revision, limited trials, and wider dissemination. The product developed in this study was a mathematics textbook based on Realistic Mathematics Education (RME) for fifth-grade elementary school students. The textbook was designed to facilitate students' understanding of mathematical concepts and develop their critical thinking skills through contextual and problem-solving activities.

First, the Define stage identified students' learning needs, curriculum requirements, characteristics, and mathematical concepts through observations, interviews, and documentation at SDN 26/IV Jambi. The findings indicated that students needed concrete, visual, contextual, and systematic learning materials aligned with the Merdeka Curriculum. Five main mathematical topics were identified for the first semester of Grade V. Second, the Design stage involved developing the initial mathematics textbook based on the findings and Realistic Mathematics Education (RME) principles. A storyboard was prepared to organize the content, layout, illustrations, contextual problems, learning activities, critical-thinking tasks, reflections, and evaluations. Third, the Develop stage involved completing the textbook, validating it through three experts in design, mathematics content, and language, and revising it based on their feedback. A limited trial involving 23 fifth-grade students and one teacher was then conducted to assess practicality through response questionnaires and effectiveness through pretests, observations, and posttests measuring conceptual understanding and critical thinking. Finally, the Disseminate stage involved distributing the final textbook through the Teachers' Working Group (KKG) in Danau Sipin District and four other elementary schools with similar characteristics in Jambi Province. Teacher responses were collected to evaluate its acceptance, usability, practicality, and potential for broader implementation.

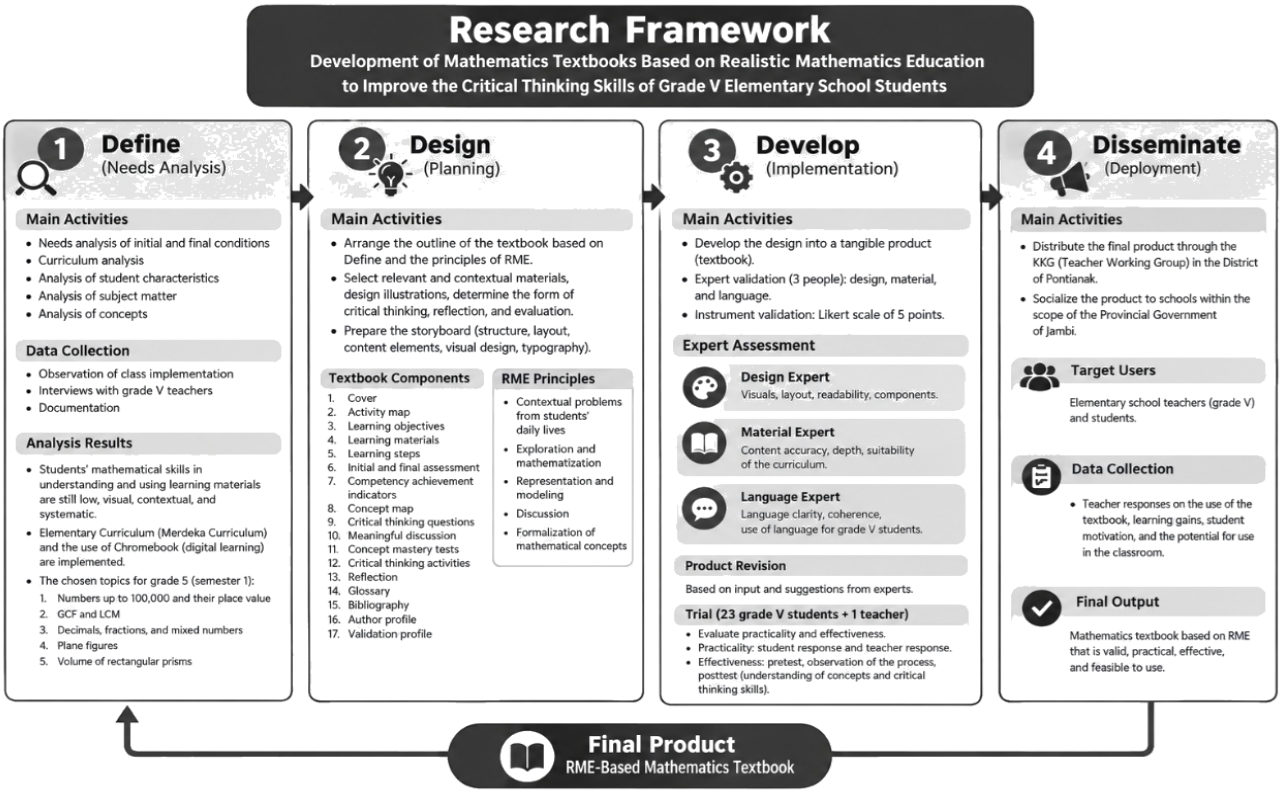


Figure 1. Research Framework

Participant

The limited implementation of the developed mathematics textbook involved 23 fifth-grade students of SDN 26/IV Jambi, with one fifth-grade classroom teacher serving as a practitioner and supporting informant. The students were selected purposively based on the characteristics of the research setting, including the implementation of the Merdeka Curriculum and the identified need for improved mathematics learning materials. Three experts participated in the product validation stage: one design expert, one mathematics material expert, and one language expert. The experts evaluated the initial product and provided recommendations for revision. In the dissemination stage, elementary school teachers participating in the KKG in Kecamatan Danau Sipin, as well as teachers from other schools with similar characteristics, provided feedback on the final product.

Data Collection

Data were collected through observations, interviews, questionnaires, tests, and documentation. During the Define stage, observations and interviews were conducted with the fifth-grade teacher and students to identify curriculum conditions, learning needs, student characteristics, learning difficulties, existing teaching materials, learning strategies, and available facilities. Documentation was used to obtain information concerning curriculum documents, teaching materials, and the learning environment.

During the Design and Develop stages, data were obtained from the storyboard and product development process, expert-validation questionnaires, and revision records. The expert validation questionnaires were used to assess the validity of the textbook's design, mathematical content, and language. Expert comments and suggestions were used as qualitative information to improve the product.

During the limited trial, questionnaires for teachers and students were administered to assess the product's practicality. Pretests and posttests were administered to measure students' mathematical conceptual understanding and critical-thinking skills before and after the use of the developed textbook. Observations were conducted during the learning process to identify students' critical-thinking activities, including understanding problems, providing reasons, applying mathematical concepts, and drawing conclusions. Documentation was collected throughout the research process to support the development and implementation data.

In the Disseminate stage, questionnaires were distributed to teachers participating in dissemination activities to gather information on the product's suitability, usability, attractiveness, acceptance, and potential for use in other elementary schools.

Instrument

The research instruments consisted of observation guidelines, interview guidelines, expert-validation questionnaires, teacher-response questionnaires, student-response questionnaires, conceptual-understanding tests, critical-thinking tests, critical-thinking observation sheets, and dissemination questionnaires. The expert validation questionnaires used a five-point Likert scale ranging from 1 to 5. The design validation instrument assessed the cover, layout, visual presentation, organization, and completeness of the textbook. The material validation instrument assessed the accuracy, relevance, completeness, systematic organization, and alignment of the content with the Merdeka Curriculum. The language validation instrument assessed word choice, terminology, sentence structure, readability, grammar, spelling, and suitability for fifth-grade students. The teacher and student response questionnaires were used to assess the textbook's practicality. The teacher questionnaire covered aspects of presentation, content, language, ease of use, and suitability for students' learning needs. The student questionnaire assessed clarity, contextual relevance, ease of following learning procedures, usefulness, motivation, learning independence, and suitability of the exercises. The conceptual understanding test was administered as a pretest and a posttest. The test was developed based on five indicators: (1) restating mathematical concepts, (2) classifying objects according to their properties, (3) providing examples and non-examples, (4) representing concepts in various forms, and (5) applying concepts

to solve problems. The test consisted of essay questions to enable students to demonstrate their understanding and reasoning processes. The critical-thinking test was also administered as a pretest and posttest. The indicators included (1) analyzing mathematical problems, (2) determining appropriate solution strategies, (3) providing logical reasons for answers, (4) considering the credibility or relevance of information, and (5) drawing conclusions based on the results of mathematical analysis. The critical-thinking observation sheet was used during the learning process to examine students' critical-thinking activities. The observed indicators included understanding problems, providing reasons, applying mathematical concepts, and drawing conclusions. Each indicator was assessed using a three-point scale: 1 = poor, 2 = fair, and 3 = good.

Data Analysis

The data were analyzed using both quantitative and qualitative descriptive approaches. Quantitative analysis was used to assess product validity, practicality, dissemination responses, students' conceptual understanding, and the development of critical thinking. Qualitative analysis was used to interpret interview results, observation findings, expert comments, suggestions, and descriptions of students' learning activities.

Validity

Product validity was determined based on assessments by the design, material, and language experts. Each expert used a five-point Likert scale. The percentage of validity was calculated by comparing the total score obtained with the maximum possible score:

$$Vs = \frac{\sum x}{\sum n} 100\%$$

Description:
Vs represents the percentage of instrument validity, ∑x represents the total score obtained from the assessment items, and ∑n represents the maximum total assessment score.

Table 1. Validity Criteria

Percentage	Category
80%–100%	Very Valid
60%–79.99%	Valid
40%–59.99%	Fairly Valid
20%–39.99%	Less Valid
0%–19.99%	Not Valid

The developed textbook was considered sufficiently valid when the overall validation result fell within the fairly valid category.

Practicality

Product practicality was determined from teacher and student responses after the limited trial. The responses were measured using a five-point Likert scale. The percentage of practicality was calculated using:

$$Vs = \frac{\sum x}{\sum n} 100\%$$

Description:
Vs represents the percentage of instrument practicality, ∑x represents the total score obtained from the assessment items, and ∑n represents the maximum total assessment score.

Table 2. Practicality Criteria

Percentage	Category
80%–100%	Very Practical
60%–79.99%	Practical
40%–59.99%	Fairly Practical
20%–39.99%	Less Practical
0%–19.99%	Not Practical

The textbook was considered practical when the overall result fell into the fairly practical category.

Effectiveness Analysis

The effectiveness of the mathematics textbook was assessed by changes in students' conceptual understanding and critical-thinking skills. Effectiveness data were obtained from pretest and posttest scores and supported by observations of students' critical-thinking processes**.**

Conceptual Understanding

Students' conceptual understanding was measured using pretest and posttest scores. The improvement in students' scores was analyzed using the normalized gain (N-Gain) proposed by Hake:

$$N\text{-}Gain = \frac{\text{Skor Posttest} - \text{Skor Pretest}}{\text{Skor Maksimal} - \text{Skor Pretest}}$$

The interpretation of N-Gain scores is presented in Table 3.

Table 3. N-Gain Criteria

N-Gain Score	Category
≥ 0.70	High
0.30–<0.70	Medium
< 0.30	Low

The textbook was considered effective in improving conceptual understanding when the average N-Gain reached at least the medium category.

Critical Thinking

Critical-thinking skills were examined using pretest and posttest scores and supported by classroom observations. The pretest and posttest results were analyzed using the same N-Gain formula:

$$N\text{-}Gain = \frac{\text{Skor Posttest} - \text{Skor Pretest}}{\text{Skor Maksimal} - \text{Skor Pretest}}$$

Critical-Thinking Achievement Percentage:

$$P = \frac{\sum x}{\sum n} \times 100\%$$

Description:
P= percentage of critical-thinking achievement
$\sum x$= total observed score
$\sum n$= maximum possible score

The observation results were interpreted using the following criteria:

Table 4. N Gain value

N-Gain Value	Category
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Medium
$g < 0.30$	Low

The quantitative observation results were complemented by qualitative descriptions of students' activities in identifying problems, providing logical reasons, applying mathematical concepts, and drawing conclusions.

Dissemination Analysis

Data obtained during the Dissemination stage were analyzed descriptively using the five-point Likert scale. The analysis covered the suitability of the content, the clarity of presentation, the ease of use, the attractiveness, the acceptance, and the potential for wider implementation.
The dissemination percentage was calculated using:

$$D=\sum n/\sum x\times 100\%$$

D = Percentage of dissemination acceptance
$\sum$**x** = Total score obtained
$\sum$**n** = Maximum possible score
The results were interpreted as follows:

Table 5. Dissemination Category

Percentage	Category
80%–100%	Very Feasible
60%–79.99%	Feasible
40%–59.99%	Fairly Feasible
20%–39.99%	Less Feasible
0%–19.99%	Not Feasible

FINDINGS

The development research on a mathematics textbook based on Realistic Mathematics Education (RME) employed the 4D development model, comprising four stages: Define, Design, Develop, and Disseminate. The Define stage was conducted to identify the product's needs and characteristics through analyses of needs, curriculum, learners, and concepts. The Design stage focused on designing the content and format of the RME-based mathematics textbook. The Develop stage involved design, material, and language validation, as well as product testing to determine its practicality. Subsequently, the Disseminate stage involved disseminating the developed product through the KKG (Teacher Working Group) forum.

Define

The Define stage aimed to obtain an overview of the mathematics learning conditions, the needs of teachers and learners, curriculum alignment, learner characteristics, and the mathematical concepts to be included in the textbook. The needs analysis showed that the mathematics abilities of fifth-grade learners varied, with most learners demonstrating relatively low achievement. Of the 23 learners, 22 (95.65%) obtained pre-test scores ranging from 0 to 40. Teachers also indicated a need for learning materials that are more concrete, visual, contextual, and appropriate to the learners' conditions. These findings indicated the need for learning materials that could help learners understand mathematical concepts through meaningful and contextual learning experiences.

The curriculum analysis showed that the school implements the Merdeka Curriculum; therefore, the textbook was developed in accordance with learning in Phase C. The learning activities were directed toward conceptual understanding, problem-solving, strategy exploration, discussion, reasoning, and the conclusion of the RME approach. In addition, the learner analysis indicated that learners had varying levels of mathematical ability, and some experienced difficulties when mathematical concepts were presented in an abstract form. Therefore, the textbook was designed to incorporate illustrations, concrete examples, everyday-life problems, exploratory activities, and discussions to support learners in developing their understanding of mathematical concepts.

The concept analysis identified five groups of mathematics topics for Grade 5, Semester 1, namely whole numbers and place value, Least Common Multiple (LCM) and Greatest Common Factor (GCF), decimal, whole, and fraction numbers, congruence, angles, perimeter and area of plane figures, and volume of solid figures. These materials were systematically arranged by considering the relationships among concepts and were connected to contextual problems in accordance with the characteristics of RME. Thus, the results of the Define stage indicated that the required product was a contextual, visual, systematic, and digital RME-based mathematics textbook for Grade 5, Semester 1, designed to facilitate learners in exploring problems, developing strategies, engaging in discussions, and constructing mathematical conceptual understanding.

Design

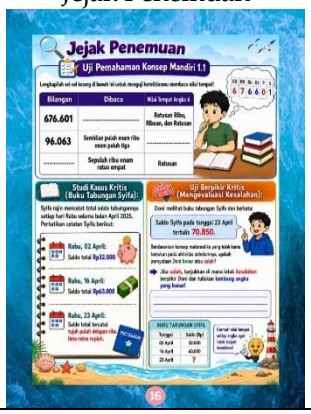
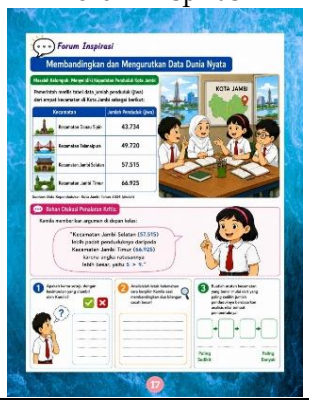
The Design stage was conducted to develop the initial design of the RME-based mathematics textbook, informed by the needs and characteristics identified in the *Define* stage. The design process considered the characteristics of fifth-grade elementary school learners, the requirements of the Merdeka Curriculum, and the objectives of developing learning materials that support conceptual understanding and critical thinking. The design activities included preparing the required materials and tools, designing the RME-based content, and developing the initial prototype of the mathematics textbook. The textbook was designed using Canva Pro/Premium and subsequently converted into a digital flipbook via Heyzine, with the learning activities aligned with the available teaching plan.

The content design integrated the principles of Realistic Mathematics Education (RME) by beginning each learning activity with contextual problems related to learners' everyday experiences. Learners were then guided to explore problems, develop solution strategies, discuss their findings, compare different strategies, and gradually construct formal mathematical concepts. This approach was implemented through several learning components, namely *Ruang Eksplorasi, Jejak Penemuan, Forum Inspirasi, Kristalisasi Konsep, Galeri Konsep, Arena Penalaran, Jejak Refleksi, and Evaluasi*. Each component was designed to provide a specific learning experience, ranging from contextual exploration and mathematical discovery to discussion, conceptual reinforcement, critical reasoning, reflection, and assessment.

The initial prototype was subsequently developed by integrating the learning materials, RME activities, illustrations, questions, exercises, summaries, reflection activities, and evaluation into a unified digital textbook. The product was designed in Canva Pro/Premium, exported as a PDF, and then published via Heyzine Flipbook. The initial prototype consisted of several components, including the cover, learning motivation, table of contents, *Ruang Eksplorasi, Jejak Penemuan, Forum Inspirasi, Kristalisasi Konsep, Galeri Konsep, Arena Penalaran, Jejak Refleksi, Evaluasi, and Glosarium*. The resulting prototype served as the initial product for the subsequent *Develop* stage, during which it would undergo validation by design, materials, and language experts before undergoing practicality and effectiveness testing.

Table 6. Design Structure of the RME-Based Mathematics Textbook

No.	Textbook Component	Function in Learning
1	Ruang Eksplorasi 	Introduces contextual problems related to learners' everyday life.

No.	Textbook Component	Function in Learning
2	Jejak Penemuan 	Guides learners to explore, try strategies, and construct mathematical concepts.
3	Forum Inspirasi 	Facilitates discussion, exchange of ideas, and comparison of solution strategies.
4	Kristalisasi Konsep 	Guides learners to formulate formal mathematical concepts based on previous activities.
5	Galeri Konsep 	Presents a concise and visual summary of important concepts.

No.	Textbook Component	Function in Learning
6	Arena Penalaran 	Provides problems that develop reasoning, analysis, and critical thinking.
7	Jejak Refleksi 	Provides opportunities for learners to reflect on their learning process and understanding.
8	Evaluasi 	Measures learners' mastery of the material and achievement of learning objectives.

Developement

The development stage involved the development and testing of the Realistic Mathematics Education (RME)-based mathematics textbook designed in the design stage. At this stage, product validation was conducted to assess the textbook's feasibility in terms of design, content, and language before its implementation in the learning process. The validation was conducted by experts in their respective fields, namely a design expert, a content expert, and a language expert. The product could proceed to the implementation stage after achieving at least a valid category. Product revisions were made based on the suggestions and feedback provided by the experts.

The validation results showed that the RME-based mathematics textbook met the feasibility criteria in all three assessed aspects. Design validation obtained 100%, categorized as very valid; content validation obtained 93.3%, also categorized as very valid; and language validation obtained 93.85%, also categorized as

very valid. These results indicate that the developed textbook met the feasibility requirements for design, content, and language use.

Table 7. Validation Results of the RME-Based Mathematics Textbook

No.	Validation Aspect	Score	Percentage	Category
1	Design	85/85	100%	Very Valid
2	Content	56/60	93.3%	Very Valid
3	Language	61/65	93.85%	Very Valid

The design validation achieved 100% and was categorized as very valid. This result indicates that the book size, layout, typography, visual hierarchy, cover design, image quality, illustrations, navigation, and placement of exercises and evaluations met the feasibility criteria. Based on the validation results, there were no mandatory revision notes for the design aspect; therefore, the product could proceed to the next stage.

In terms of content, the textbook obtained a percentage of 93.3%, categorized as very valid. This result indicates that the content was aligned with the learning outcomes and objectives, students' characteristics, mathematical concepts, sequence of presentation, and the learning approach employed. Although the textbook was categorized as very valid, several suggestions for improvement were provided, including simplifying the cover design, increasing the font size, simplifying the preface, improving the arrangement of learning objectives and indicators, reducing unnecessary images, and updating illustrations that were no longer relevant.

These suggestions were used as a basis for improving the textbook before its implementation. Language validation achieved 93.85%, categorized as very valid. This result indicates that the language used met the criteria of clarity, readability, sentence effectiveness, cohesion and coherence, appropriate spelling and punctuation, word choice, and consistency of terminology. Thus, the textbook was considered appropriate in terms of language characteristics required for elementary school students.

The research results showed that the Realistic Mathematics Education (RME)-based mathematics textbook had a very high level of practicality. Based on the educator's response, the textbook received a score of 46 out of 50, corresponding to 92% and categorized as very practical. The students' responses in the limited trial involving six students yielded a 90% score, categorized as very practical. In comparison, the large-group trial involving 24 students achieved a 92% result, also categorized as very practical. These results indicate that the textbook was easy to use, had an attractive appearance, presented comprehensible content, met students' needs, and supported and motivated students during the learning process.

The effectiveness of the textbook was assessed by measuring improvements in students' conceptual understanding and critical thinking skills across two learning cycles, each consisting of six meetings. In Cycle I, the mean conceptual understanding score increased from 45.83 to 68.75, with an N-Gain of 0.42, categorized as moderate. Students' critical thinking skills increased from 39.58 to 59.38, with an N-Gain of 0.33, also categorized as moderate. In Cycle II, the mean conceptual understanding score increased from 52.08 to 76.04, with an N-Gain of 0.50, categorized as moderate. In contrast, critical thinking skills increased from 45.31 to 68.75, with an N-Gain of 0.43, categorized as moderate. Thus, the N-Gain for conceptual understanding increased from 0.42 to 0.50, while the N-Gain for critical thinking skills increased from 0.33 to 0.43.

Observations during the learning process also indicated the development of students' critical thinking skills. In Cycle I, the mean critical thinking score increased from 2.10 in Meeting 1 to 2.53 in Meeting 2 and 2.96 in Meeting 3. In Cycle II, the mean score increased from 2.89 in Meeting 4 to 2.93 in Meeting 5 and 3.07 in Meeting 6. This development was reflected in students' ability to understand problems, provide reasoning, and apply mathematical concepts in solving contextual problems.

Disseminate

The dissemination stage was conducted to examine teachers' responses and obtain an overview of students' responses to the Realistic Mathematics Education (RME)-based mathematics textbook.

Dissemination was conducted through a Teacher Working Group (Kelompok Kerja Guru/KKG) forum that involved five fifth-grade teachers from several elementary schools in Jambi City. The digital textbook and its user guide were distributed to the participants, followed by a demonstration of the textbook's characteristics, structure, usage procedures, and examples of learning activities.

The teacher response questionnaire consisted of 17 statements and yielded a score of 326 out of a maximum score of 340, corresponding to 95.88%. Based on the dissemination category, the textbook was classified as very feasible. All teachers responded positively to the alignment of the content with fifth-grade mathematics learning, the use of real-life contexts, problem-solving activities, discussions, ease of use, visual presentation, and the textbook's ability to help teachers facilitate students' conceptual understanding.

According to the teachers' responses, students also demonstrated positive reactions. All teachers reported that students were enthusiastic to very enthusiastic and that the textbook was helpful to very helpful in supporting students' understanding of the learning materials. The activities considered most supportive of learning included problem solving, discussion, visualization, and the application of mathematical concepts to everyday life. These findings indicate that the RME characteristics embedded in the textbook can support student engagement and conceptual understanding through contexts closely related to students' experiences.

Nevertheless, the dissemination stage also identified several challenges, including unstable internet connections, limited access to devices, limited time to use computer facilities, and the need to provide learning materials or props. Teachers also suggested simplifying the language, reducing content density on several pages, adding more problem-solving activities, and providing a printed version as an alternative. All respondents stated that they were willing to use the textbook again.

Overall, the dissemination results indicated that the RME-based mathematics textbook achieved a 95.88% response rate among teachers and was categorized as very feasible according to the dissemination criteria. The textbook also received positive student responses, as observed by teachers, and was considered suitable for continued use in fifth-grade mathematics instruction. The feedback obtained at this stage provides a basis for further product refinement, particularly in terms of language, content density, variety of problem-solving activities, and alternative access to the textbook.



Figure 1. Final Product

DISCUSSION

The development of the mathematics textbook based on Realistic Mathematics Education (RME) employed the 4D development model, consisting of Define, Design, Develop, and Disseminate. The selection of the 4D model provided a systematic framework for developing the instructional product based on learning needs, designing it according to students' characteristics, validating and revising it through expert review, and introducing it to a broader audience. In this study, the 4D model resulted in a mathematics textbook that integrates the characteristics of RME through real-life contexts, exploration activities, strategy development, discussion, and a gradual transition toward formal mathematical concepts.

The Define stage involved an analysis of learning needs, learner characteristics, curriculum requirements, and mathematical concepts. The findings indicated that students experienced difficulties when dealing with abstract mathematical concepts, particularly when learning was predominantly oriented toward formulas and procedural instruction. This condition became the basis for determining the characteristics of the developed textbook, particularly the need for contextual situations, visual representations, and learning activities that enable students to construct mathematical concepts through meaningful experiences. This finding is consistent with Hakim & Sitepu, (2024), who reported that students' difficulties in understanding mathematical concepts can be addressed through RME by connecting abstract concepts with real-life situations and concrete representations.

The Design stage translated the results of the needs analysis into the structure of the textbook and RME-based learning activities. The textbook was organized into four main sections: Exploration Space, Discovery Path, Inspiration Forum, and Concept Crystallization. This structure provides a learning sequence that moves from problems closely related to students' experiences toward mathematical mathematization and formal concept formation. Rather than directly introducing formulas, students are given opportunities to understand situations, develop solution strategies, compare different approaches, and formulate conclusions. (Cevikbas & Kaiser, 2020). This structure is consistent with the principles of RME, which position realistic contexts as the starting point for meaningful mathematical learning.

Previous studies have also emphasized the importance of instructional materials that integrate real-life contexts with mathematical concepts. Alim et al. (2021)For example, a study developed a mathematics textbook using the RME approach and found that practical situations helped connect mathematical concepts to contextual problems. The developed product obtained an average validity score of 88% and practicality scores ranging from 87.50% to 95.99%, indicating that RME can be incorporated not only as a learning approach but also directly into instructional materials.

The Develop stage transformed the instructional design into a complete product that could be implemented in classroom learning. The textbook was subsequently subjected to expert validation to determine the appropriateness of its design, content, and language. Feedback from the validators was used as the basis for product revision. This process demonstrates that the textbook's development was iterative, meaning the final product was not solely based on the initial design but was refined through expert evaluation and user feedback. (Silva, 2026).

The Disseminate stage was conducted by introducing the textbook to Grade V teachers through a Teacher Working Group (KKG) forum. This stage provided additional information on the product's acceptance beyond the main implementation context. Overall, the four stages of the 4D model established a continuous relationship between needs analysis, pedagogical design, expert validation, product implementation, and user acceptance.

Validity of the RME-Based Mathematics Textbook

The validation results showed that the textbook obtained validity percentages of 100% for the design aspect, 93.33% for the content aspect, and 93.85% for the language aspect. All three aspects were categorized as very valid according to the criteria used in the study. These findings indicate that the developed textbook fulfilled the required feasibility criteria prior to classroom implementation.

The 100% validity score for the design aspect indicates that the visual and technical elements of the textbook, including layout, typography, illustrations, navigation, and page presentation, were appropriate for the characteristics of the developed product. These elements are important because an RME-based mathematics textbook not only serves as a source of information but also guides students through a sequence of mathematical activities.

The content validity score of 93.33% indicates that the mathematical content was consistent with the learning outcomes and instructional objectives. The content was also organized according to mathematical accuracy and the characteristics of RME-based learning. The presentation of contextual problems provides

students with opportunities to develop solution strategies before being guided toward formal mathematical representations.

Meanwhile, the language validity score of 93.85% indicates that the language fulfilled the requirements of readability, clarity of instructions, appropriateness for students' developmental levels, and accuracy of terminology. Language is particularly important in RME-based learning because students are required to understand problems, follow instructions, explain their strategies, and communicate their mathematical reasoning (Harahap & Sari, 2023).

These findings are consistent with previous research on the development of mathematics instructional materials. Arif & Vahlia (2026)For example, a study developed a problem-based mathematics textbook and obtained a validity score of 91%, categorized as very valid. The product also achieved practicality scores of 92.7% and 93.5% during subsequent trials. These findings indicate that systematic validation and revision can produce mathematics instructional materials that meet both content and usability requirements (Sumandya & Widana, 2022). The validators' feedback in the present study also led to several revisions, particularly regarding visual presentation and page organization, including improvements to the cover, font size, page density, and the use of illustrations. These revisions demonstrate that validation served not merely to determine the feasibility category but also as formative evaluation for improving the quality of the textbook before implementation.

Practicality of the RME-Based Mathematics Textbook

The textbook's practicality was evaluated based on teacher and student responses. The results showed practicality percentages of 92% among teachers, 90% among students in the limited trial, and 92% among students in the larger-group trial. All three results were categorized as very practical. These findings indicate that the textbook can be used for mathematics learning and is well received by its users.

The product's practicality was supported by the clarity of instructions, textbook presentation, content organization, contextual problems, and learning activities that provided students with opportunities to explore and discuss mathematical problems. The use of contextual situations enabled students to connect mathematical activities with their own experiences. This characteristic is important in RME because realistic contexts serve as a starting point for students to construct mathematical understanding.

These findings are consistent with Shahidayanti, T., Prahmana, R. C. I., & Fran, (2024), who developed an RME-based textbook and obtained practicality that instructional materials connecting mathematical concepts with practical situations can achieve high levels of user acceptance. The present findings are also consistent with Nurlaila et al. (2025), who reported that practicality can be achieved when instructional materials provide clear structures, appropriate content, and learning activities that can be easily followed by teachers and students.

Improvement in Conceptual Understanding and Critical Thinking

The implementation results demonstrated improvements in students' conceptual understanding and critical thinking following instruction using the RME-based mathematics textbook. Students' conceptual understanding obtained an N-Gain score of 0.42 in Cycle I and increased to 0.50 in Cycle II. Meanwhile, critical thinking obtained an N-Gain score of 0.33 in Cycle I and increased to 0.43 in Cycle II. Both aspects were categorized as moderate.

The improvement in conceptual understanding is consistent with previous studies demonstrating that RME can support mathematical understanding through meaningful contexts. RME improved elementary students' mathematical conceptual understanding compared with conventional learning (Rangkuti et al., 2024). This provides further support for the use of RME to strengthen mathematical conceptual understanding. Thus, the improvement in conceptual understanding observed in the present study is consistent with the general tendency reported in previous research.

The improvement can be explained by the characteristics of RME activities, which guide students from contextual situations toward formal mathematical concepts. Students first encounter problems that can be understood through their experiences, then develop solution strategies, use representations, discuss their findings, and connect their strategies with formal mathematical concepts. This process provides opportunities for students to establish relationships among real-life situations, mathematical models, and formal concepts.
Critical thinking also improved, with the N-Gain increasing from 0.33 in Cycle I to 0.43 in Cycle II. This finding is consistent with Aprilianto and Sutarni (2023), who reported that RME-based mathematics learning can improve elementary students' critical thinking skills. Kohar et al. (2024) similarly found that an RME-based student worksheet was valid and effective for improving the critical thinking skills of Grade V elementary students, with an effect size of 0.63, placing it in the moderate category. RME can support students' analytical, evaluative, and problem-solving abilities by connecting mathematical learning with meaningful contexts. It also has a positive influence on students' mathematical critical thinking abilities (Koerunnisa et al., 2025).

The development of critical thinking in the present study was also reflected in the observation results. In Cycle I, the average observation score increased from 2.10 in Meeting 1 to 2.96 in Meeting 3. In Cycle II, the average score was 2.89 in Meeting 4, increased to 2.93 in Meeting 5, and reached 3.07 in Meeting 6. This pattern indicates that the development of critical thinking does not necessarily occur linearly in every meeting. When students encounter new materials or learning activities, their performance may initially fluctuate before improving through continued learning experiences and discussion.

The findings of Anugraheni et al. (2025) similarly demonstrate that RME can support critical thinking and mathematical reasoning among elementary students, particularly through contextual learning activities. These findings reinforce the argument that RME-based activities provide opportunities for students to analyze information, develop strategies, justify their reasoning, and make mathematical decisions.
Overall, the improvement in conceptual understanding and critical thinking observed in this study is consistent with previous research. However, the present study differs in its focus because RME was not merely implemented as a teaching approach but was integrated directly into a developed mathematics textbook. The contribution of this study, therefore, lies in translating RME principles into a systematic instructional material structure comprising Exploration Space, Discovery Path, Inspiration Forum, and Concept Crystallization.

Dissemination of the RME-Based Mathematics Textbook

The Dissemination stage was conducted through a KKG forum involving Grade V teachers outside the main implementation context. Responses from five teachers reached 95.88%, which was categorized as very good. This result indicates that the textbook was well received among the participating teachers. Their responses highlighted the use of everyday contexts, visual presentation, problem-solving activities, and opportunities for discussion as relevant features for mathematics learning.
The positive responses suggest that the textbook's pedagogical characteristics may be useful beyond the original implementation setting. However, the broader use of digital instructional materials also depends on the availability of devices, internet connectivity, access to computer laboratories, and other learning resources. These factors can affect whether teachers and students can consistently access the material, particularly in schools with limited digital infrastructure. Consequently, the pedagogical quality of a textbook must be accompanied by an implementation strategy that considers differences in school facilities.

One practical solution is to provide an offline-accessible version of the textbook. Core learning materials, contextual problems, illustrations, and student activities can be made available in downloadable formats so that teachers and students do not need a continuous internet connection to use the essential content. Where devices are available but connectivity is unreliable, teachers can download the materials in advance and distribute them via local storage or school devices. If the textbook includes online videos or other media, the essential instructional information should also be represented through text, illustrations, or alternative activities that remain accessible offline.

A second strategy is to prepare a printable version of the core learning materials. Printed pages can retain the main RME learning sequence, including contextual problems, exploration tasks, spaces for student responses, discussion prompts, and concept summaries. This option is particularly relevant when students do not have individual devices or when access to the computer laboratory is restricted. The digital and printed versions should maintain equivalent learning objectives so that differences in infrastructure do not prevent students from engaging with the central mathematical activities.

A third strategy is to organize technology use through shared devices and collaborative learning. When the number of available devices is limited, students can work in small groups to examine digital resources, discuss contextual problems, and compare their strategies. Teachers can also display selected materials using a shared classroom screen where such facilities are available. This arrangement can reduce dependence on individual device ownership while preserving opportunities for mathematical discussion and reasoning.

Teachers' preparation is another important consideration. Providing simple implementation guidance, downloadable files, and instructions for accessing digital resources can help teachers integrate the textbook into their existing classroom routines. The KKG forum may serve as a channel for sharing these implementation strategies and exchanging experiences with the use of RME-based materials across different school settings. Such collaboration could support the broader adoption of the textbook without assuming that all schools have the same technological resources.

These strategies represent practical recommendations derived from the infrastructure challenges identified during dissemination. They should not be interpreted as interventions whose effectiveness was established by the present study, because the reported results do not include a comparative evaluation of offline materials, printed versions, or shared-device arrangements. Future research could examine whether these adaptations improve accessibility, teacher implementation, and student learning outcomes in schools with different levels of digital readiness.

Compared with previous studies, the present research demonstrates both similarities and differences. Earlier research has established RME's potential to improve conceptual understanding and critical thinking, and it has been incorporated into various instructional materials, including student worksheets and mathematics textbooks. (Ramidha et al., 2025). The present study extends this work by organizing RME activities into a structured textbook comprising Exploration Space, Discovery Path, Inspiration Forum, and Concept Crystallization. This organization provides a systematic progression from contextual understanding to formal mathematical reasoning.

Furthermore, the study positions RME not only as a classroom teaching approach but also as a framework for developing instructional materials. Its contribution lies in integrating pedagogical principles, textbook structure, and opportunities for mathematical reasoning within a product developed through the 4D model. At the same time, the dissemination findings indicate that the broader implementation of such materials requires attention to infrastructure, accessibility, and teacher readiness. The positive teacher responses also indicate that the characteristics established during the *Define* stage remained relevant when the product was introduced beyond the main implementation context (Sliwka et al., 2026). The combination of pedagogical design and context-sensitive implementation is therefore important for supporting the sustainable use of RME-based mathematics textbooks.

In conclusion, the developed textbook demonstrated high validity, practicality, and positive acceptance among participating teachers. The improvements in conceptual understanding and critical thinking indicate promising learning outcomes. However, the moderate N-Gain scores and fluctuations in observation results suggest that students' development was not uniform across all learning activities. The textbook's alignment with the Merdeka Curriculum is reflected in its contextual, exploratory, collaborative, and concept-building learning sequence. However, broader implementation requires strategies that accommodate differences in digital infrastructure. Future studies should examine the effectiveness of offline and printed adaptations, investigate factors associated with fluctuations in critical thinking, and assess the textbook's transferability to schools with different learning conditions.

CONCLUSION

The RME-based mathematics textbook for Grade V elementary school students was successfully developed using the 4D model (Define, Design, Develop, and Disseminate). The textbook was categorized as very valid, with scores of 100% for design, 93.33% for content, and 93.85% for language. Its practicality scores ranged from 90% to 92%, while teacher acceptance during dissemination reached 95.88%. Students' conceptual understanding improved, with N-Gain increasing from 0.42 to 0.50, while critical thinking increased from 0.33 to 0.43. Both outcomes remained in the moderate category, indicating potential for further improvement.

This study has several limitations, including implementation in a specific educational context, moderate learning gains, and digital infrastructure constraints that may affect broader implementation. Therefore, teachers are encouraged to adapt the textbook's contextual activities to students' needs and provide more opportunities for reasoning, discussion, and evaluation of mathematical solutions. Providing printable and offline-accessible versions is also recommended for schools with limited digital facilities. Future research should involve more diverse schools, examine the textbook's long-term effectiveness, and evaluate its offline and print versions. Comparative studies may also provide stronger evidence of its contribution to students' conceptual understanding and critical thinking. These efforts are expected to support further development and broader implementation of RME-based mathematics textbooks.

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