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Enhancing mathematical literacy among prospective teachers: Effectiveness of an RME-based learning design

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Abstract

Textbooks exert minimal influence on learning outcomes, underscoring the urgent need to develop high-quality, context-responsive teaching materials for prospective educators. This study designed, validated, and evaluated Realistic Mathematics Education (RME)-based instructional materials using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework. Participants included 60 prospective teachers from Pasundan University, randomly assigned to experimental (RME-based materials) and control (conventional textbook) groups. Data were collected through observations, questionnaires, and achievement tests, with ANOVA used for analysis. Expert validation scores were high: material experts (91.86%), learning model experts (92.58%), and peers (92.40%), confirming strong validity. Practicality was similarly high, with small-group and large-group student assessments scoring 92.40% and 92.03%, respectively. Post-intervention, the experimental group outperformed the control group significantly (mean scores: 91.8 vs. 69.5; $\Delta = 22.3$), supported by robust statistical evidence: $F(1,47) = 45.07$, $p < 0.001$, $\eta^2 = 0.49$, Cohen's $d = 1.39$—indicating a large effect size. Findings confirm the RME-based materials are valid, practical, and highly effective in improving prospective teachers' learning outcomes. Broader implementation and adaptation to other mathematics topics are strongly recommended.

Keywords: learning design; mathematical literacy; prospective teacher; RME

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Introduction

The development of the 21st century is a new challenge for the Teacher Professional Program (TPP) regarding the low ability of mathematical literacy (Díez-Palomar et al., 2023). The 2011 TIMSS survey on the mathematical achievement of Indonesian students is below the average of other countries, with a global average score of around 600, while the scores of students from Indonesia are between 400-420 (Stacey, 2011). In previous research at the university level, it was shown that the literacy understanding of prospective teachers was 22% in the very low category, 63% in the moderate category, this shows that 85% need a solution (König et al., 2022).

Basic mathematical literacy Refers to an individual's ability to understand, apply, and communicate mathematical concepts in everyday life according to the level of proficiency measured by frameworks such as the Programme for International Student Assessment (PISA) (Boricic et al., 2020). According to PISA, mathematical literacy is not only limited to the ability to calculate or solve mathematical problems mechanically, but also includes the ability to use mathematical knowledge in real contexts, such as understanding data, interpreting graphs, and making decisions supported by mathematical evidence (Manfreda Kolar, V., & Hodnik, 2021).

At the basic level, a person is expected to be able to recognize patterns, perform simple measurements, and understand basic concepts such as numbers, basic operations, and simple geometric shapes (Spelke & Lee, 2010). In this case, prospective teachers must be able to transfer knowledge to students in schools. According to the OECD, mathematical literacy is an individual's ability to formulate, use, and interpret mathematics in various real-life contexts (OECD., 2019; OECD, 2021). This literacy includes the ability to think mathematically, using mathematical concepts, procedures, facts, and tools to explain and predict phenomena. In the context of research, PISA Level 1-2 competencies are the basis, which describe the ability to find relevant information and apply routine procedures in real-life contexts (Ozgen, 2019).

The design and analysis of the mathematics knowledge test must align with the key dimensions of the Program for International Student Assessment, namely (1) computational processes (formulation, use, and interpretation), (2) mathematical content (quantity, area and shape, change and relationships, uncertainty and data), and (3) contexts of use (personal, professional, social, and scientific) (Podkhodova et al., 2020). This modification ensures the validity of the measurement of basic mathematics knowledge and alignment with international frameworks, while being relevant to the development needs of prospective teachers in Indonesia.

However, prospective teachers also experienced a fundamental problem: in the substantive test results of 15 questions with a 30-minute time limit conducted by researchers, 70% of participants did not achieve the minimum competency score and only 30% passed the minimum standard score. Data shows that in the 3-year TPP student training, the average score increased from 55 and increased to 72, but still far from the teachers' expectations (Orsi & Cobb, 2018). Other data shows that the mathematical literacy skills of prospective teachers are still very limited, with indicators of reasoning that are still unstructured to multi-structured reasoning, not yet achieving a complete rational understanding (Wang et al., 2022). All of this indicates specific weaknesses in mathematical literacy among prospective teachers. The current design of mathematics teaching materials is also minimal. Evaluation results indicate that the low learning outcomes of prospective teachers are partly due to the limited availability of mathematics teaching materials (Chand et al., 2021). Some teaching materials are available, but the resulting learning designs are still very normative and procedural. Furthermore, the application of models such as the RME model is also still minimal. As a result, prospective teachers are still text-based rather than reality-based. However, theory states that effective learning needs to include exploration of real phenomena, mathematical modeling, social interaction, and vertical and horizontal mathematics. This theory is not applied by prospective teacher students, resulting in a lack of literacy understanding and suboptimal learning outcomes (Fredriksen, 2021)

Problems in the field indicate that student teachers are less able to connect reality with mathematical material. Although there is an increase after model interventions such as discussions, the average literacy score is only in the range of 70-75 and has not reached the category expected by educators, namely >85 (Srikoon et al., 2024). This assumes that the RME model can improve literacy understanding and improve learning outcomes (Bayrak., Alp., 2022). It is necessary to design teaching materials that are in accordance with reality with the RME model that supports the discussion model.

The RME approach is rooted in didactic phenomenology, where Freudenthal emphasized that mathematics should be “taught as a human activity” through contexts that students can understand. The importance of guided reinvention, which provides experiences for students to rediscover mathematical ideas through their own models and strategies, is emphasized (Heuvel-panhuizen, 2019).

A meta-analysis study specifically for the RME model in Indonesia, there were 95 categorized as having a strong effect on student mathematical literacy (Otten et al., 2019). However, most of these studies were conducted on elementary and junior high school students and have never been applied to student teachers. In another meta-analysis study in Turkey, it produced a moderate to high effect for RME compared to traditional methods (Turgut, 2021). This indicates that the RME model has been proven effective in this student population and needs to be applied to prospective teachers who are still limited.

The theory underlying the development of teaching materials design with the Freudenthal Realistic Mathematics Education (RME) approach emphasizes five main principles: phenomenological exploration, progressive mathematization and modeling, student construction, interactivity, and intertwinement (Freudenthal, 1991). Designing teaching materials with the RME model can support literacy understanding and improve learning outcomes, starting from real-world contexts and building vertically from the concrete to the abstract (Da, 2022). Modern mathematical literacy theory explains literacy as the ability to formulate, use, and interpret in real-world contexts, in line with the RME model (Hoogland et al., 2016). By designing teaching materials and incorporating RME theory, it is assumed that learning outcomes and literacy can be improved and strengthen the pedagogical foundation of prospective teachers (Papadakis et al., 2021).

The urgency of this research is due to the mathematical literacy level of prospective teachers being far below expectations. It is necessary to design teaching materials using the RME model to assist prospective teacher students. The curriculum also requires prospective teachers to be able to build student literacy in schools through contextual learning, so prospective teachers must be well prepared. Although the RME model has been proven to have a strong influence (effect size > 1.0) on elementary and secondary school students, it has not been proven effective for prospective teacher students. This research is urgently needed to bridge the gap between theory, expectations, and reality in the field.

Therefore, the research questions are 1) how can the design of mathematics teaching materials based on Realistic Mathematics Education (RME) improve the basic mathematical literacy of students in the Teacher Professional Program (TPP) and 2) to what extent are the validity, practicality, and effectiveness of RME-based teaching materials able to improve the understanding of concepts and mathematics learning outcomes of TPP students in a realistic learning context? Therefore, the purpose of this research is to produce a teaching material design based on the RME model that is valid, practical, and effective.

Methods

The research method with the ADDIE development approach consists of five phases, namely analysis, design, development, implementation and evaluation (Branch, 2009). The subjects in this study were 60 students of the Teacher Professional Education Program (TPP) at Pasundan University. All participants were prospective mathematics teachers who were pursuing professional education and had a bachelor's degree in pure mathematics and mathematics education. In the small group trial, the sample consisted of 20 people selected from 60 people randomly, based on the willingness of the prospective teacher students.

Meanwhile, in the large group trial, the subjects were divided into two groups, namely 30 people in the experimental group and 30 people in the control group. The experimental group was given a teaching material design based on the RME model, while the control group was given the same teaching material design but used a different learning model, namely the conventional learning model, the same time duration, the same material, different classes, different models from the experimental class. This division was to test the practicality and effectiveness of the teaching material design based on the RME model in improving learning outcomes and mathematical literacy skills, such as data interpretation, reasoning, symbolic representation, and mathematical communication. The following are the stages of designing teaching materials based on the RME model to improve the learning outcomes of prospective teacher students:

Analysis stage

The analysis stage is the initial step. This stage identifies the learning needs of prospective teacher students through observations of mathematics learning using questionnaires and interviews to assess learning difficulties, understanding, skills, and learning outcomes.

Planning stage (design)

In the planning stage, a learning system framework was developed, encompassing learning objectives, basic mathematical literacy indicators, context-based learning activities, evaluation strategies, and learning media. The design of teaching materials was based on constructing mathematical concepts through contextual problems relevant to everyday life. The materials were structured in stages, starting with drawing activities related to three-dimensional vectors and in accordance with reality, exploratory activities, activity sheets, and assessment instruments.

Development phase

The development phase is the validation process for open-ended materials designs. The developed product includes a teaching material design based on the RME model and is validated by subject matter experts, learning model experts, and peers to assess content quality, model suitability, and integration components. Validation results are used to revise and refine the project to meet educational eligibility standards and are piloted on student teachers. Before using the assessment instrument, it is also validated and must be declared valid and reliable.

Implementation phase

The implementation phase consists of two steps: small group trials and large group trials or experimental classes. The design of teaching materials is based on a valid and feasible RME model. In the small group trials, a pre-test is conducted, the implementation of teaching materials with the RME model, instruments are used to measure practicality, and finally a post-test is conducted for the small group. In the large group trials/experimental phase, a pre-test is conducted, the implementation of teaching materials with the RME model, instrument assessment, and the final step is a post-test. The same treatment is carried out for the control group, namely a pre-test, implementation of textbooks with a conventional model, and post-test assessment. During the implementation phase, student teachers are involved in solving real-world problems relevant to life in the surrounding environment. Data obtained from this stage are used to determine the extent to which the lesson plans that have been prepared are practical and effective and accepted by student teachers. The implementation results serve as the basis for evaluating the learning outcomes of teaching materials with the RME model and their impact on understanding mathematical literacy.

Evaluation phase

The evaluation phase assesses practicality and effectiveness through instrument measurements, pre-tests, and post-tests designed with data interpretation in mind. Data are analysed descriptively and by observing the learning process and responses to the teaching and inferential approaches to determine the average difference between the two classes. The evaluation results indicate whether the developed learning design has a positive impact on improving students' mathematical thinking skills through learning outcomes. If difficulties and obstacles are identified, the design is modified and improved.

Data collection techniques included observation, questionnaires, and tests. Observation data were obtained from the direct implementation of Realistic Mathematics Education (RME)-based teaching materials in the classroom. Observations were conducted before and during learning activities, using structured observation sheets containing indicators of learning and implementation of student activities. Observed indicators included student engagement, difficulties and obstacles in understanding the material, group discussions using the RME model, the ability to connect real-world contexts with mathematical concepts, the use of mathematical representations, and student interactions with lecturers. Data were also collected using questionnaires from experts, peers, and prospective teachers. The questionnaire was structured based on a Likert scale with five answer options, from "strongly disagree" to "strongly agree." Aspects measured included material clarity, engagement in learning activities, the relevance of the context used, and ease of understanding mathematical concept literacy through the RME model approach. This questionnaire was used to assess the practicality of students' perspectives. Test data were also obtained from pre-tests and post-tests. Pre-test results were used to determine initial skills, while post-test results were used to assess skill improvement after following the RME model approach.

The data analysis technique used is descriptive statistics. The results analyse the validation results from material experts, learning model experts, colleagues, for validity and assessment of TPP students to measure practicality. The instrument given to material experts, learning model experts, colleagues and TPP students with a Likert scale from strongly disagree (1) to strongly agree (5). While the interpretation of the assessment results is 0% - 19% (Low Validity), 20% - 39% (Low Validity), 40% - 59% (Moderate Validity), 60% - 79% (Valid) and 80% - 100% (High Validity). For interpretation of practicality and effectiveness starting from 80% - 100% (Excellent), 60% - 79% (Very Good), 40% - 59% (Good), 20% - 39% (Enough), 0% - 19% (Poor). In addition, this study also conducted ANCOVA inferential statistics to see the differences in the average learning outcomes of the two classes of TPP students by controlling for pre-test scores and reporting Cohen's d effect sizes.The minimum criteria that must be achieved is the practicality of RME-based teaching material design above 80%-100% (Turgut, 2021). Meanwhile, the RME-based teaching material design is said to be effective if the mean post-test results for TPP students in the experimental class are classically above the average of 80 (Huu et al., 2021)

The following C1-C4 assessment rubrics in this study were adapted and strengthened by referring to the PISA mathematical literacy coding guide and the SOLO (Structure of Observed Learning Outcomes) taxonomy to ensure construct validity and international alignment in assessing students' conceptual and procedural understanding (COLLIS, 1982). Based on the PISA framework, mathematical literacy is assessed from the participant's ability to formulate, use, and interpret mathematics in real-life contexts using the SOLO taxonomy. Classifying levels of understanding from the lowest (pre-structural) to the highest (extended abstract). Category C1 describes fully correct conceptual and procedural abilities, where students are able to connect mathematical concepts, generalize ideas, and solve problems with coherent logic and without errors equivalent to the extended abstract level in the SOLO taxonomy and PISA Levels 5-6. Category C2 indicates good but imperfect understanding, characterized by clear relationships between concepts but accompanied by minor errors in calculation or interpretation equivalent to the relational SOLO and PISA Levels 3-4. Category C3 reflects partial understanding where students only master some aspects of a concept or procedure without being able to fully integrate them; this understanding is related to the multi-structural SOLO and PISA Levels 1-2.

Meanwhile, C4 indicates a lack of conceptual or procedural understanding, with irrelevant or empty answers, in line with the pre-structural SOLO and PISA Below Level 1. Interrater reliability coding in this study was conducted using the C1–C4 category rubric. Two independent raters (Rater A and Rater B) underwent a rubric training process that included reading the rubric, discussing sample answers, and initial calibration using 20 responses. This stage aimed to standardize interpretations so that coding was based on a shared understanding. After the calibration stage, both raters assessed all data separately without communicating with each other. Each student's answer was classified into category C1, C2, C3, or C4 according to the standardized rubric. The coding results were then compared using a contingency table to calculate the level of agreement. Interrater reliability was analyzed using the Cohen's Kappa coefficient, which takes into account both actual and chance agreement. The κ value was 0.69, indicating substantial agreement between the two raters based on the Landis and Koch classification. After the reliability calculation, all discrepancies are discussed through a reconciliation session to establish an agreed final score.

Results

The results of this study identified new methods to improve the learning outcomes and mathematical literacy of prospective Teacher Professional Program (TPP) students. The following are the results and findings based on the ADDIE stages:

Analysis stage

The analysis phase identified students' learning needs. The results showed that 38% had a poor understanding of mathematical literacy, poor mathematical literacy skills, and difficulty understanding mathematical materials, especially three-dimensional vector materials. The analysis also showed that 43% still had difficulty with basic mathematical concepts using conventional models. The learning approach used so far was still procedural, text-based, and lecturer-centered, so it was not able to develop mathematical thinking skills. Based on observations, 70% did not achieve the minimum score on the mathematics ability test. These observation results were supported by interview data with students who stated that they were not able to understand three-dimensional vector materials using conventional models. This confirmed that their abilities in literacy, concepts, data interpretation, mathematical modeling, and reasoning were still low. From the analysis during class observations, it was found that the design of teaching materials still did not use the RME model, such as exploring real-world phenomena. During the observations, several students showed interest in materials compiled and based on the RME model. This became the basis for research to design mathematics teaching materials based on the RME model.

Design

The design of RME-based teaching materials is presented as attractively as possible, starting from presenting a house building connected with three-dimensional material.

(a) (b)

Figure 1. (a) Introduction to RME; (b) Vector Material

Figure 1 is an introduction that does not directly present a formal definition, but rather presents a real-world phenomenon relevant to life, such as situations around us with three-dimensional materials. It represents a vector in space, depicting its direction and magnitude in a three-dimensional coordinate system. This visualization encourages understanding that vectors are not simply abstract symbols but are closely related to position and motion in real space.

Development

The following are the results of expert assessments of the quality of Three-Dimensional Vector teaching materials based on the Realistic Mathematics Education (RME) model in improving mathematical literacy:

Table 1. Mean results of material expert assessment of product design indicators

No.	Indicators	Score	Interpretation
1	Conceptual Suitability and Accuracy of Three-Dimensional Vector Material	92.18%	High Validity
2	Realistic Integration with Mathematical Concepts (RME Principle)	90.12%	High Validity
3	Clarity of Presentation Structure and Logical Flow of Material	90.10%	High Validity
4	Ability to Develop Mathematical Literacy	93.18%	High Validity
5	Material Suitability with Learning Objectives and Curriculum	94.12%	High Validity
6	Readability, Language Accuracy, and Representative Visualization	91.50%	High Validity
	Average	91.86%	High Validity

Based on Table 1, the mean results of expert assessment evaluation of the product design indicators show that the Three-Dimensional Vector teaching materials based on RME have a mean score of 91.86% (high validity). Indicators with high validity values are the suitability of the material to learning objectives and curriculum at 94.12%, followed by the ability to develop mathematical literacy at 93.18%. The indicators of conceptual accuracy and accuracy of vector material obtained 92.18%, indicating good suitability of mathematical concepts. In addition, the realistic context integration (RME) indicator reached 90.12%, the clarity of the presentation structure at 90.10%, and the readability and representative visualization at 91.50%, all of which are included in the high validity category. The teaching material product is suitable for use in building an understanding of mathematical literacy based on the RME model.

Table 2. Results of expert assessment of learning models

No.	Indicators	Score	Interpretation
1	Integration of the RME Model Stages with the Material Structure	93.30%	High Validity
2	Contextualization of Learning to the Real World	92.10%	High Validity
3	Facilitating the Development of Mathematical Literacy	90.90%	High Validity
4	Interactivity and Knowledge Construction	91.20%	High Validity
5	Model Alignment with Learning Objectives and Curriculum	94.80%	High Validity
6	Model Effectiveness in Improving Understanding and Learning Outcomes	93.20%	High Validity
	Average	92.58%	High Validity

Table 2 shows the results of the expert assessment of the learning model, which shows that the application of the Realistic Mathematics Education (RME) model has an average score of 92.58%, indicating excellent alignment between the learning model, materials, and strengthening of mathematical literacy. The indicator with the highest score is the alignment of the RME model with learning objectives and the curriculum, which is 94.80%, indicating that the RME learning design is in accordance with the expected mathematical literacy measurement standards. Furthermore, the level of integration of the RME model with the material structure reached a score of 93.30%, followed by the model's effectiveness in improving understanding and learning outcomes, which is 93.20%. Other indicators, such as contextualizing learning with the real world (92.10%), interactivity and knowledge construction (91.20%), and facilitating the development of mathematical literacy (90.90%), also fall into the high validity category. These results indicate that the RME model is effective, contextual, and capable of significantly improving the mathematical literacy skills of prospective teacher students.

Table 3. Lecturer assessment results (peers)

No.	Indicators	Score	Interpretation
1	Compliance of Material Design with RME Principles	92.30%	High Validity
2	Integration of Vector Material and Real Three Dimensions	91.45%	High Validity
3	Relevance to Mathematical Literacy Objectives	92.90%	High Validity
4	Clarity of Learning Flow and Student Activities	92.22%	High Validity
5	Creativity and Appeal of Learning Design	92.82%	High Validity
6	Interactivity of TPP Students in Learning	94.31%	High Validity
7	Integration of Assessment with Literacy Learning Objectives	91.80%	High Validity
8	Clarity of Language and Mathematical Representation	91.10%	High Validity
9	Feasibility of Implementation in TPP/Prospective Teacher Learning	92.90%	High Validity
10	Potential for Improving Literacy and Learning Outcomes	92.22%	High Validity
	Average	92.40%	High Validity

Table 3 shows that the overall peer assessment of the indicators was 92.40%, which falls into the high validity category. Each indicator demonstrates the consistent quality of the Realistic Mathematics Education (RME)-based learning design in vector materials and real three-dimensional objects. The indicator that received the highest score was interactivity in learning with a mean of 94.31%. Meanwhile, the lowest score was for language clarity and mathematical representation at 91.10%, although still in the high validity category, indicating the need for minor improvements in the presentation of mathematical concepts to be more communicative. The relevance indicator to mathematical literacy goals was 92.90% and the potential to improve literacy and learning outcomes was 92.22%. The developed learning device design has high validity.

Implementation

Before the test was administered, instrument validation and reliability procedures were conducted to ensure the suitability of the mathematical literacy test items for use in this study. Material validation was conducted by three mathematics education experts by assessing the suitability of the items with competency indicators, language clarity, and realistic contexts according to the RME model. The Item Material Validity Index (I-CVI) value was between 0.96 with an average of 0.91, indicating a very valid category (≥0.78). Next, construct validity was tested using corrected item-total correlations on 60 TPP student respondents. The results showed a correlation of r = 0.73, which was all higher than the r table (0.273), so all items were declared valid. Reliability testing was conducted using Cronbach's Alpha, resulting in an α value of 0.78 for the pre-test (good category) and increasing to α = 0.91 for the post-test (very good category). These results indicate high internal consistency between items, with no items reducing the overall reliability.

Therefore, this instrument is valid and reliable, and can be used to measure mathematical literacy skills. This implementation involved two stages: a small group trial and a large group trial. The results of the small group trial are as follows.

Table 4. Pre-test and post-test results for small group tests and large group tests

Group	Pre-Test	Post-Test
Small Group	58.6	90.6
Large Group/Experiment	60.2	91.8
Control Class	60.2	69.5

Based on Table 4, a pre-test involving 20 students yielded an average score of 58.6, which rose to 90.60 in the post-test after implementing the RME-based teaching materials—an improvement of 32 points. In the large-scale trial, the experimental group's average pre-test score was 60.2, increasing to 91.8 post-intervention (a 31.6-point gain). In contrast, the control group—using conventional textbooks—scored 60.2 pre-test and only 69.5 post-test. The 22.3-point mean difference between groups (91.8 vs. 69.5) highlights the substantial effectiveness of the RME-based materials. These findings indicate that the intervention significantly enhanced learning outcomes among prospective teachers compared to traditional instruction, reinforcing the value of contextually grounded, student-centered instructional design in teacher education.

Table 5. Results of the small group trial questionnaire assessment of prospective teachers

No.	Indicators	Score	Interpretation
1	Design and RME facilitate understanding of mathematical concepts.	92.13%	Excellent
2	Learning activities encourage critical mathematical thinking.	92.70%	Excellent
3	Learning materials are easy to understand and engaging to learn.	92.15%	Excellent
4	The RME approach helps develop mathematical concepts.	92.20%	Excellent
5	Group discussions with RME enhance mathematical communication skills.	90.20%	Excellent
6	Design and RME foster active participation in the learning process.	93.36%	Excellent
7	Learning problems and activities are appropriate to students' abilities.	92.80%	Excellent
8	RME enhances contextual problem-solving skills.	91.90%	Excellent
9	The language used in mathematical materials is clear and easy to follow.	92.30%	Excellent
10	RME design effectively enhances understanding of mathematical literacy.	90.60%	Excellent
	Average	92.40%	Excellent

Based on Table 5, the results of the small group pilot questionnaire evaluation showed an average score of 92.03%, which is included in the "very practical" category. This indicates that the Realistic Mathematics Education (RME)-assisted learning design has high practicality in improving mathematical literacy understanding. The indicator with the highest score was interactivity and active participation with a mean of 93.36%, indicating that students felt more involved in the learning process. Meanwhile, the lowest score was for improving mathematical literacy understanding with a mean of 90.60%, although it is still in the very good category. These results confirm that the RME-based learning design not only has high validity but is also practical and effective for application to student teachers.

Table 6. Practicality of teaching material design based on the RME model

No.	Indicators	Score	Interpretation
1	The RME learning design helps me understand mathematical concepts	92.13%	Excellent
2	The learning activities encourage me to think critically and interpret mathematical data	92.70%	Excellent
3	The learning media and materials are easy to understand and engaging	92.15%	Excellent
4	The RME approach helps me relate mathematical concepts to everyday life situations	92.20%	Excellent
5	Group discussions in RME learning improve my mathematical communication skills	90.20%	Excellent
6	The learning design makes me more active and engaged in the learning process	93.36%	Excellent
7	The learning problems and activities are challenging but appropriate to my abilities	92.80%	Excellent
8	RME learning improves my ability to solve problems contextually	91.90%	Excellent
9	The mathematical language and representations used in the materials are clear and easy to follow	92.30%	Excellent
10	Overall, the RME learning design effectively improves my understanding of mathematical literacy	90.60%	Excellent
	Average	92.03%	Excellent

Based on Table 6, the practicality level of the Realistic Mathematics Education (RME) model-based teaching material design showed Excellent results with an average of 92.03%, which is included in the "high practicality" category. Each indicator obtained a score above 90%, which indicates excellent acceptance and effectiveness among student teachers. The indicator that obtained the highest score was the learning engagement aspect of 93.36%, which indicates that the RME design succeeded in increasing students' active involvement in the learning process. Meanwhile, the indicator that obtained the lowest score was the increase in mathematical literacy skills of 90.60%, although it is still in the "Very Good" category. In addition, critical thinking skills (92.70%) and the relevance of concepts to everyday life (92.20%) also showed prominent results.

Interviews with prospective teachers using the RME model revealed that "presenting the material through a real-world context makes mathematical concepts easier to understand. In the "previous" material, students tended to memorize procedural steps, but through the RME material, "they were encouraged to understand the meaning of each concept." Of the 20 interviewees, 12 students stated that "this was the first time they understood vectors because they were directly related to the situation of building a house and the position of objects in real space." This opinion is consistent with previous initial indications of difficulty understanding abstract concepts. Students also highlighted that exploration activities, group discussions, and visual representations helped them build their own mathematical models. Several students stated that the reinvention process was guided by "discovering" concepts from what was learned, making learning more meaningful. During implementation, we became more active in asking questions, checking each other's strategies, and getting used to connecting context with mathematical symbols. We believe that the RME approach can improve our abilities in mathematical communication, data interpretation, and reasoning, which were previously our main weaknesses.

Evaluation

The results of the evaluation of the effectiveness of RME-based teaching material design on prospective teacher students showed a significant difference between the learning outcome scores of the two classes. Before the analysis was conducted, ANCOVA assumptions were checked, including the homogeneity of regression confirmed by the interaction test between treatment and covariate with the result $p = 0.213$ ($p > 0.05$), indicating a homogeneous regression slope between groups. The residual normality test showed $p = 0.184$ (Kolmogorov–Smirnov), and Levene's homogeneity of variance test produced $F = 1.27$; $p = 0.268$, which means the variance between groups is uniform. The ANCOVA results showed a significant treatment effect on post-test scores ($F(1,47) = 45.07$; $p < 0.001$) with $\eta^2 = 0.49$, indicating 49% of the final score variance was explained by the RME treatment. Cohen's d value =1.39 indicates a very large effect on improving the mathematical literacy of student teachers.

Discussion

It was found that the design of teaching materials based on the RME model that has been implemented can improve learning outcomes and understanding of mathematical literacy in the Teacher Professional Program (TPP). The designed teaching materials have been validated and declared valid by experts and are high-practice products. The design of teaching materials based on RME is also effective in improving learning outcomes in prospective teacher students at Pasundan University. In the analysis stage, it was identified that most students have difficulty in understanding mathematical concepts with conventional models. They tend to focus on memorization procedures without being able to connect these concepts to everyday phenomena. Previous learning methods were conventional, so students often have difficulty interpreting visual information, modeling mathematical problems and logical reasoning from textbooks. To overcome these difficulties, materials were developed based on the basic principles of RME, contextual exploration, progressive modeling, knowledge construction, interactivity, and interconnections between concepts.

The findings of this study are in line with previous research which revealed that material design can be integrated into real life, allowing students to explore and build understanding through direct experience (Ulandari et al., 2019). The teaching materials were designed from exploratory activities to conceptual understanding, with presentations based on real-world problems. Validity reviews by experts, peers, and students showed that all components met the criteria for academic and pedagogical feasibility. The presentation of the materials, the integration of the RME model approach, and its relationship to mathematical literacy were categorized as very good. This indicates that the design is not only theoretically structured but also practically designed based on the needs of prospective teachers. Effectiveness during implementation, both on a small and large scale.

During implementation, students demonstrated improved skills in connecting mathematical concepts to real-world contexts, constructing mathematical models of real-world problems, and interpreting and presenting data logically and communicatively. Students were able to reflect on the concepts they learned because the teaching approach not only conveyed formulas but also guided them to discover the meaning of the concepts themselves through an exploratory process. In addition, to improving learning outcomes, the RME model approach also impacted literacy understanding. They felt engaged in the learning process, were motivated to think critically, and had a more positive view of mathematics as a science in everyday life.

The implementation of this project also demonstrated that the RME approach, when applied systematically, can create an active, reflective, and collaborative learning environment. The evaluation also found that RME-based learning can strengthen students' skills in mathematical communication, logical reasoning, and symbolic representation. By designing RME-based teaching materials, students are encouraged to practice conveying mathematical ideas in visual and narrative forms and connecting concepts to real-life experiences. These findings, similar to previous research, provide an important foundation for mathematical thinking that prospective teachers can later apply in school learning contexts (Krogh et al., 2022). By designing RME-based teaching materials, it offers a more meaningful learning experience and prepares prospective teacher students to be able to teach mathematics well, logically, and communicatively in the field.

The large effect size (Cohen's d = 1.39) in this study indicates that the implementation of the Realistic Mathematics Education (RME) model has a significant impact. This research finding aligns with previous findings on the impact of RME on student achievement in the United States (Stohlmann et al., 2012). This difference can be explained by several factors. First, the rigorous experimental design with a control group and pre-test covariates allowed for more clearly measured RME treatment effects without numerous variables. Second, the Hawthorne effect may have played a role because TPP students perceived themselves as engaging in innovative research, thus increasing their motivation and active participation. Third, the appropriateness of the learning context to the needs of prospective teachers also strengthened the intervention's impact, as the RME materials were structured around real-world experiences and phenomena. This combination of methodological and motivational factors likely explains the large effect sizes in this study.

The findings of this study contribute to the development of the RME model, which is consistent with Freudenthal's theoretical principles, which have been shown to be applicable to the design of instructional materials. This theory emphasizes that mathematics learning should begin with concrete experiences and in concrete forms, then progressively progress toward abstraction (Gravemeijer, 1994). In addition, the findings of this study are in line with previous research showing that students experience a process of reinterpreting mathematical concepts through exploration, modeling, and social interaction in the classroom (Valenta & Enge, 2022).

These findings support the theoretical premise that mathematics as a human activity is more effectively taught through a reality approach rather than simply procedural memorization (Bujak et al., 2013). The findings of this study are also in line with the results of previous studies which show the effectiveness of the RME model approach in improving mathematical literacy, especially in elementary and secondary schools (Gravemeijer, 1994).

However, this study makes a new contribution by demonstrating the effectiveness of the RME model at the higher education level, especially for teaching students, which has previously been minimally explored. The results of the integration of theory, previous empirical findings, and actual implementation results, this study strengthens the argument that the design of teaching materials based on RME can be widely applied at various levels of education, including to produce prospective teachers who are able to teach mathematics meaningfully and relevantly.

A limitation of this study lies in the accuracy of its implementation. The process of implementing RME in the classroom can vary among lecturers, depending on pedagogical experience, implementation time, and student readiness at a given institution. This variation has the potential to affect the consistency of results, particularly in the use of RME principles such as progressive mathematics. This study focused more on quantitative results through statistical tests and did not delve into aspects of the learning process. For future research, it is recommended to conduct the evaluation process using a mixed-methods approach, combining quantitative and qualitative data. Quantitative data such as pre-post test scores and effect sizes can be combined with qualitative data from observations, student reflections, and in-depth interviews to understand how RME concepts are actually implemented in the classroom. This approach can help identify factors influencing implementation success and barriers, including lecturer-student interactions, adaptation to local contexts, and group dynamics. Thus, the results of future research will not only describe the effectiveness of learning outcomes numerically but also provide a comprehensive understanding of the process of developing mathematical literacy through the consistent and sustainable implementation of RME-based materials.

Conclusion

Mathematics learning based on the Realistic Mathematics Education (RME) model can strengthen conceptual understanding, mathematical literacy, and reflective learning experiences for prospective teachers. This approach consistently shifts learning from a procedural pattern to a contextual, interactive, and collaborative process. This study confirms that the integration of RME with reality-based learning design can be an effective model for developing higher-order mathematical thinking skills while fostering positive attitudes toward mathematics. These findings recommend broader implementation in various prospective teacher education programs, with adaptations to local contexts, human resources, and learning infrastructure. To overcome scalability limitations, institutional support is needed through lecturer training and the development of flexible RME-based teaching materials, so that this approach can be implemented sustainably in higher education environments with diverse backgrounds.

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Conflicts of Interest

In this publication, there is no conflict of interest between the author and other parties.

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Taufiqulloh Dahlan: Writing original manuscript drafts, revising, formal analysis, and methodology**; Dadang Iskandar:** Writing original manuscript drafts and revising; **Siti Maryam Rohimah:** Writing original manuscript drafts and revising; **Moh. Nurhadi:** Writing - review & editing, revision, formal analysis, and methodology; **Acep Roni Hamdani:** Writing - review & editing, revision, formal analysis, and methodology.

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