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The development and evaluation of mathematics learning materials based on realistic mathematics education with a scientific approach to enhance students' learning outcomes

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Abstract

This study aims to develop, describe learning activities, and test the effectiveness of mathematics learning materials based on Realistic Mathematics Education (RME) with a scientific approach on the topic of sequences and series. The study uses the 4-D development model, which includes the stages of define, design, develop, and disseminate. The developed materials consist of Lesson Plans (RPP), Student Worksheets (LKS), and Learning Outcome Tests (THB). The research subjects were tenth-grade science students (X MIPA) at SMA Negeri 1 Dringu. Data were collected through validation sheets, observations of learning activities, observations of teachers' ability to manage learning, student response questionnaires, and learning outcome tests. The results show that the developed learning materials meet very valid criteria, with validation percentages of 91.30% for RPP, 90.18% for LKS, and 91.03% for THB. Learning activities showed that students were actively engaged in observing contextual problems, discussing, formulating problem-solving strategies, communicating results, and drawing mathematical conclusions. The practicality of the materials is demonstrated by teachers' ability to manage learning at 96.23%, students' positive responses to learning at 96.76%, and positive responses to the materials at 89.35%. The effectiveness of the materials is indicated by the experimental class's posttest average score of 84.3, higher than the control class's 72.5, with a t-value of 7.21 and significance of 0.000. The N-Gain value of the experimental class was 0.68, also higher than the control class's 0.42. Thus, RME-based learning materials with a scientific approach are declared valid, practical, effective, and capable of supporting more meaningful mathematics learning activities.

Keywords: Realistic Mathematics Education; Scientific approach; Learning activities; Learning materials; Sequences and series; Mathematics learning outcomes

1. Introduction

Mathematics plays an important role in developing logical, systematic, critical, creative, and analytical thinking skills. In the context of 21st-century education, mathematics learning is not only aimed at mastering formulas and procedures but also at students' abilities to understand problems, develop problem-solving strategies, communicate ideas, and connect mathematical concepts to real-life situations. This aligns with the view that mathematics learning should provide meaningful learning experiences so that students can use mathematical knowledge flexibly in various contexts [1,2].

One of the problems often encountered in mathematics learning is the low level of active student involvement during the learning process. Teacher-centered instruction can cause students to merely receive information, imitate procedures, and have fewer opportunities to construct concepts independently. As a result, students' mathematical

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understanding tends to be procedural and less connected to the real-life experiences they face daily [3,4]. Therefore, learning materials are needed that can facilitate students to actively observe, ask questions, discuss, explore, conclude, and communicate mathematical ideas.

The topic of sequences and series is an important part of mathematics but is often considered abstract by students. Concepts such as patterns, the n-th term, the sum of terms, and their application in contextual problems require understanding that is not only symbolic but also conceptual. If this material is taught only through formulas and routine exercises, students may have difficulty understanding the meaning of the concepts and applying them to real-world problems. Therefore, teaching sequences and series needs to be designed through activities that allow students to recognize patterns from context, construct mathematical models, and gradually draw generalizations [5,6].

Realistic Mathematics Education (RME) is a learning approach that is relevant for addressing these issues. RME emphasizes that mathematics should be learned through meaningful human activities, starting from contextual problems and then directed towards horizontal and vertical mathematization processes. Through this approach, students not only learn the final results in the form of formulas but also engage in the process of discovering, comparing strategies, representing ideas, and building conceptual understanding. The main principles of RME position real-life contexts as the starting point of learning, use models as bridges to formal concepts, and leverage classroom interactions as a means to strengthen mathematical understanding [7,8].

In addition to RME, the scientific approach also serves as an important foundation in learning because it encourages students to learn through the stages of observing, questioning, experimenting or collecting information, reasoning, and communicating. These stages provide students with the opportunity to be actively involved in the learning process, rather than merely receiving the material. In mathematics learning, the scientific approach can help students develop critical and systematic thinking skills through investigative activities, discussions, and presentation of results. Therefore, integrating RME with the scientific approach has the potential to create mathematics learning that is more contextual, active, and meaningful [9,10].

The development of learning materials is an important aspect to ensure that the learning approach can be implemented systematically in the classroom. Learning materials such as Lesson Plans (RPP), Student Worksheets (LKS), and Learning Outcome Tests (THB) need to be designed in an integrated manner so that objectives, activities, content, and evaluation support each other. In development research, the quality of learning materials is generally assessed in terms of validity, practicality, and effectiveness. Valid materials demonstrate content and construct appropriateness, practical materials indicate ease of implementation, and effective materials show a positive impact on students' learning outcomes [11,12].

However, the study of developing learning materials should not stop at product validity and improvements in learning outcomes. The process of learning activities also needs to be described because these activities show how the developed materials actually function in the classroom. Learning activities serve as important evidence that the RME and scientific approaches are not only written in the design of the materials but are also implemented through student activities in understanding contextual problems, engaging in group discussions, formulating problem-solving strategies, presenting results, and drawing mathematical conclusions. By including descriptions of learning activities, this article can provide a more complete picture of the relationship between tool design, implementation processes, and student learning outcomes [13,14].

Several previous studies have shown that learning innovations based on activities, research, real-life contexts, and integrated approaches can improve students' thinking skills. Sumarno et al. demonstrated that the implementation of RBL-STEM can support the improvement of students' financial literacy in controlling consumptive behavior [15]. Izza et al. developed RBL-STEM instructional materials to enhance students' combinatorial thinking skills in solving graph coloring problems and their applications in batik motif design [16]. In addition, Mursyidah et al. and Mufidati et al. also showed that the development of RBL-STEM-based learning materials can improve students' computational and conjectural thinking abilities through solving mathematics problems connected to real-world applications [17,18].

Although several studies have shown the importance of developing innovative learning materials, there is still a need for research that specifically integrates RME, the scientific approach, and descriptions of learning activities on the topic of sequences and series. Many development studies focus more on validation results and effectiveness, while explanations of how students engage during the implementation of the materials are not always detailed. In mathematics learning, however, the learning process is an essential part of understanding why a tool can improve students' learning outcomes. Therefore, this study places learning activity as an important part of the discussion, in addition to the validity, practicality, and effectiveness of the learning materials [11,14].

Based on this background, this study aims to develop mathematics learning materials based on Realistic Mathematics Education with a scientific approach on the topic of sequences and series. The study also aims to describe students' learning activities during the implementation of the materials, particularly activities such as observing contextual problems, engaging in discussions, formulating problem-solving strategies, communicating results, and drawing mathematical conclusions. In addition, the study aims to evaluate the quality of the materials based on validity, practicality, and effectiveness in relation to students' learning outcomes. Thus, this research is expected to contribute to the development of mathematics learning that is not only oriented toward the product of the materials but also on the quality of the learning activity process and the achievement of students' learning outcomes [7,9,12].

2. Materials and Methods

2.1. Research Design

This study is a development research (research and development) aimed at producing mathematics learning materials based on Realistic Mathematics Education (RME) with a scientific approach on the topic of sequences and series. The learning materials developed include Lesson Plans (RPP), Student Worksheets (LKS), and Learning Outcome Tests (THB). In addition to producing learning materials, this study also examines students' learning activities during the implementation of the materials and tests the effectiveness of the materials on students' mathematics learning outcomes.

The development model used is the 4-D model, which consists of four stages: define, design, develop, and disseminate. The define stage is used to identify learning needs, student characteristics, content concepts, learning tasks, and learning objectives. The design stage is used to design the learning materials and research instruments. The develop stage involves expert validation, tool revision, and learning trials. The disseminate stage is carried out through the distribution of the developed materials and reporting of research results.

In addition to the development approach, this study also uses a quasi-experimental design with two groups: an experimental class and a control class. The experimental class receives learning using RME materials with a scientific approach, while the control class receives conventional learning as normally conducted in the school. Both classes are given pretests and posttests to determine improvements in learning outcomes.

2.2. Research Location and Subjects

The research was conducted at SMA Negeri 1 Dringu, Probolinggo Regency, during the even semester of the 2014/2015 academic year. The population of the study consisted of all tenth-grade students at SMA Negeri 1 Dringu. The research sample was randomly selected from six available classes. Class X MIPA 1 was designated as the experimental class, while Class X MIPA 2 was designated as the control class.

The experimental class received treatment in the form of mathematics learning based on RME with a scientific approach using the developed learning materials. The control class followed conventional learning according to the teaching patterns normally applied by the teacher. The material used in this study was sequences and series. Learning was conducted in five meetings with a total allocation of 10 class hours, while the learning outcome test was administered in one meeting with a duration of 2 class hours.

2.3. Procedure for Developing Learning Materials

The development procedure for learning materials was carried out using the 4-D model, which includes the stages of define, design, develop, and disseminate. In the define stage, an initial-final analysis was conducted through curriculum review, interviews with teachers and students, and identification of learning problems on the topic of sequences and series. This stage also includes analysis of student characteristics, content concepts, tasks, and formulation of learning objectives to ensure that the developed materials align with learning needs.

In the design stage, the initial draft of the learning materials was prepared, consisting of Lesson Plans (RPP), Student Worksheets (LKS), and Learning Outcome Tests (THB). The RPP was designed based on the RME syntax integrated with the scientific approach, while the LKS contained contextual problems, discussion activities, guiding questions, and conclusion-drawing activities. The THB was prepared to measure students' learning outcomes. At this stage, research instruments were also developed, including validation sheets, observation sheets, student response questionnaires, and learning outcome tests.

In the development stage, the materials were validated by experts to assess content and construct suitability, language, format, material feasibility, and alignment with RME and the scientific approach. The validation results were used as the basis for revisions before implementing the materials in the experimental class. During implementation, student activities, teacher activities, teachers' ability to manage learning, and student responses were observed to assess the practicality and feasibility of the materials.

In the disseminate stage, materials that met the criteria of validity, practicality, and effectiveness were prepared as the final product. Dissemination was carried out through documentation of the learning materials, reporting of research results, and preparation of scientific articles so that the materials can serve as references for other teachers or researchers in implementing RME-based mathematics learning with a scientific approach on the topic of sequences and series.

2.4. Research Method Flow

The research flow can be illustrated as follows.

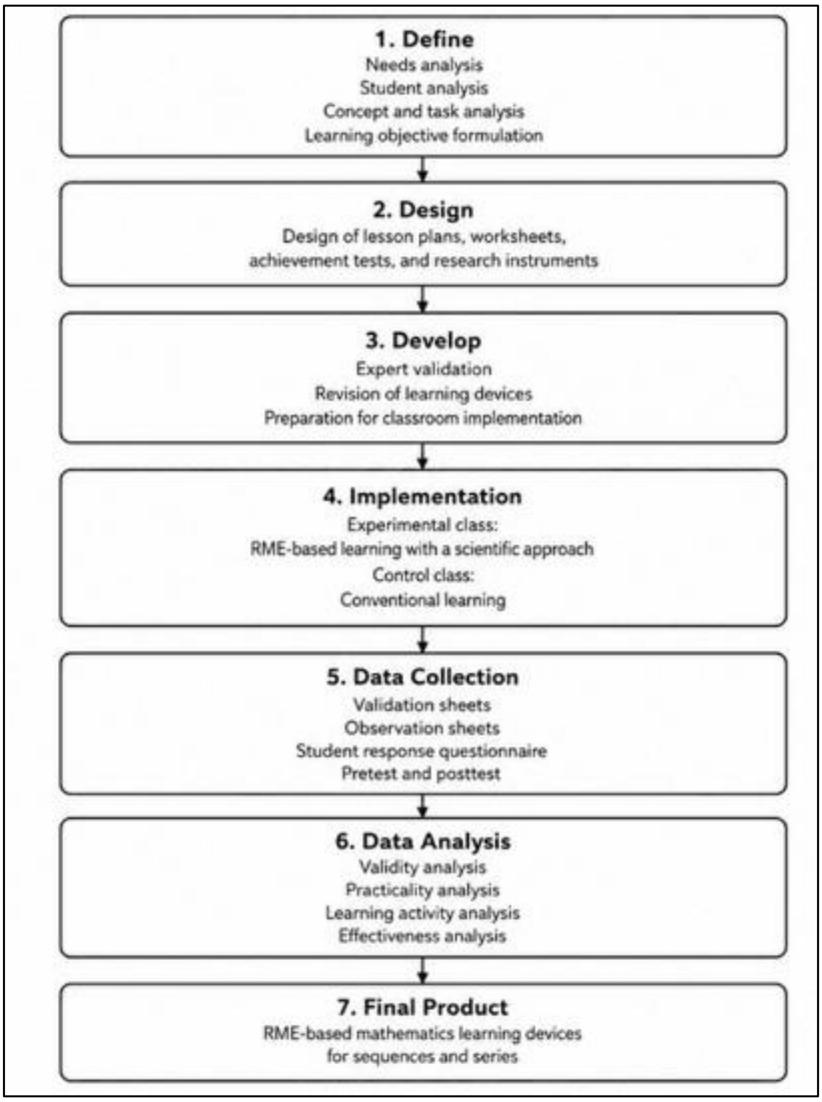

Figure 1 Research Methodology Flow: Development of RME-Based Mathematics Learning Materials with a Scientific Approach

2.5. Learning Implementation

Learning was implemented in the experimental class through five meetings designed based on the integration of RME principles and the scientific approach. At the beginning of the lesson, the teacher presented contextual problems related to sequences and series as a starting point for students to observe patterns, understand the situation, and connect real-life experiences with mathematical concepts.

Next, students were guided to ask questions, collect information, discuss in groups, and formulate problem-solving strategies through the Student Worksheets (LKS). Through these activities, students gradually built understanding, compared problem-solving strategies, and developed mathematical models from the contextual problems. The teacher acted as a facilitator, providing guidance, prompting questions, and clarifying concepts when necessary.

After the discussion, students communicated their work through presentations or explanations in front of the class, while other students had the opportunity to respond and compare answers. At the end of the lesson, the teacher and students summarized the concepts that had been learned. Thus, the learning process included the stages of observing, questioning, experimenting, reasoning, and communicating, and reflected RME principles through the use of context, models, student constructions, interactions, and concept connections.

2.6. Research Instruments

Research instruments were used to measure validity, practicality, learning activities, student responses, and the effectiveness of learning outcomes. Validation instruments were used to assess the feasibility of Lesson Plans (RPP), Student Worksheets (LKS), and Learning Outcome Tests (THB). The RPP validation sheet included aspects such as subject identity, indicators, learning objectives, content, learning resources and media, learning model, lesson scenario, and assessment. The LKS validation sheet covered aspects of format, illustrations, language, content, and questions, while the THB validation sheet included aspects of format, language, content, question construction, and alignment with learning indicators.

Observation instruments were used to record student activities, teacher activities, and teachers' ability to manage learning according to RME steps and the scientific approach. Observed student activities included paying attention to teacher or peer explanations, reading books or worksheets, writing relevant information, discussing or asking questions, and behaviors not related to learning. In addition, a student response questionnaire was used to determine students' feedback on learning activities and the materials used, while the learning outcome test was used to measure students' abilities on sequences and series and to compare the effectiveness of learning between the experimental and control classes.

2.7. Data Collection Techniques

The research data were collected through expert validation, observation, questionnaires, and tests. Expert validation was conducted before the learning materials were used in trials. Validators assessed the RPP, LKS, and THB using prepared evaluation scales and provided suggestions for revising the materials.

Observations were carried out during the learning process. Student activity observations were conducted to determine students' engagement in RME-based learning with a scientific approach. Teacher activity observations and assessments of teachers' ability to manage learning were conducted to determine the conformity of the learning implementation with the designed materials. Student response questionnaires were administered after the learning sessions to determine students' perceptions of the learning and the materials used.

Learning outcome tests were administered in the form of pretests and posttests. The pretest was used to determine students' initial abilities in the experimental and control classes, while the posttest was used to measure learning outcomes after the treatment. The pretest and posttest results were analyzed to determine improvements in learning outcomes and the effectiveness of the learning materials.

2.8. Data Analysis Techniques

The data were analyzed using quantitative descriptive and inferential methods according to the type of data obtained. Validation data for the learning materials were analyzed by calculating the average score for each indicator, aspect, and total validity using a 1–4 scale, with the criteria of not valid, fairly valid, valid, and very valid. The materials were considered valid if they received the categories valid or very valid. Data on teachers' ability to manage learning were analyzed based on the average score of each observation aspect in each session, and the learning was considered practical if the teachers' abilities were at least in the good category. Meanwhile, student activity and response data were analyzed by calculating the percentage of relevant activities or positive responses. The activity percentage was calculated using the formula

$$P_a = \frac{A}{N} \times 100\%$$

where P_a is the percentage of activity, (A) is the total activity score obtained, and N is the total possible activity score. Student activities were considered ideal if relevant activities reached at least 80%, while irrelevant activities did not exceed 20%.

Learning outcome data were analyzed by comparing pretest and posttest scores in the experimental and control classes. Learning improvement was calculated using the N-Gain formula

$$N\text{-}Gain = \frac{Skor\ maksimum - Skor\ pretest}{Skor\ posttest - Skor\ pretest}$$

In addition, posttest results of both classes were compared using a t-test to determine significant differences in learning outcomes. Before conducting the t-test, the data were first tested for normality and homogeneity. Differences in learning outcomes were considered significant if the significance value was less than 0,05.

2.9. Criteria for the Quality of Learning Materials

The quality of learning materials is determined based on three aspects: validity, practicality, and effectiveness. The materials are considered valid if the expert validation results for the RPP, LKS, and THB are at least in the valid category; considered practical if the teacher's ability to manage learning is at least in the good category and students give positive responses to the learning and the materials used; and considered effective if students' learning outcomes in the experimental class are better than those in the control class, as reflected in posttest scores, N-Gain, mastery of learning, and statistical test results. Thus, learning materials are deemed of high quality if they meet the criteria of validity, practicality, and effectiveness, and are able to support learning activities in accordance with RME principles and the scientific approach.

3. Results and Discussion

This section presents the results of the development and implementation of mathematics learning materials based on Realistic Mathematics Education (RME) with a scientific approach on the topic of sequences and series. The research results are discussed based on four main focuses: the validity of the learning materials, learning activities during implementation, the practicality of the materials, and the effectiveness of the materials on students' learning outcomes. The discussion is organized to show the relationship between the quality of the materials, the learning process, and the achievement of students' learning outcomes.

3.1. Results of Learning Tool Development

This study produced mathematics learning materials based on RME with a scientific approach, consisting of Lesson Plans (RPP), Student Worksheets (LKS), and Learning Outcome Tests (THB). The materials were developed using the 4-D model, which includes the stages of define, design, develop, and disseminate. In the define stage, learning needs, student characteristics, the concepts of sequences and series, task analysis, and formulation of learning objectives were analyzed. The results of this stage showed that learning sequences and series require materials capable of connecting mathematical concepts with real-life contexts so that students do not merely memorize formulas but also understand the meaning of patterns and mathematical generalizations.

In the design stage, the learning materials were designed by integrating RME principles and the scientific approach. The RPP was prepared to guide teachers in conducting learning through contextual problems, group discussions, presentations, and conclusion drawing. The LKS was designed as a medium for student activities containing contextual problems, guiding questions, modeling activities, and tasks for concept conclusion. The THB was developed to measure students' learning outcomes after the learning process. Thus, the developed materials are not only oriented toward delivering material but also toward facilitating student learning activities.

In the develop stage, the materials were validated by experts to ensure the feasibility of content, construct, format, language, and alignment with RME characteristics and the scientific approach. Validation results showed that all materials were in the very valid category. This indicates that the developed materials have met theoretical feasibility and can be used in the learning process after revisions based on expert suggestions.

Table 1 Validation result of learning materials

No.	Validated tool	Validation percentage	Category
1	Lesson Plans (RPP)	91,30%	Very valid
2	Student Worksheets (LKS)	90,18%	Very valid
3	Learning Outcome Tests (THB)	91,03%	Very valid

Based on Table 1, the validation of the RPP obtained 91.30%, the LKS 90.18%, and the THB 91.03%. All three values fall into the "very valid" category. The validity of the RPP indicates that the lesson scenario, learning objectives, teacher and student activities, and assessment are in accordance with the characteristics of RME and the scientific approach. The validity of the LKS shows that the activities included in the worksheets align with the material, use language understandable by students, and guide students to construct concepts through contextual problems. The validity of the THB indicates that the test instruments match the learning indicators and can be used to measure students' learning outcomes on sequences and series.

These results align with Nieveen's view that learning development products must meet validity criteria before being implemented in the classroom [12]. The validity of the materials serves as an indicator that they have been designed based on a theoretical foundation and clear learning needs. In the context of this study, the validity also demonstrates that the integration of RME and the scientific approach can be systematically reflected in the RPP, LKS, and THB. These findings also support previous research showing that the development of activity- and context-based materials can produce learning materials that are feasible for improving the quality of mathematics learning [15–18].

3.2. Learning Activity in the Implementation of RME-Based Learning with a Scientific Approach

One important focus of this study is to describe students' learning activities during the implementation of the learning materials. This is important because the quality of learning materials is not only assessed based on validation results and learning outcomes but also on how the materials are used in the learning process. In this study, learning activities were observed over five learning sessions in the experimental class. The learning activities were designed based on the integration of RME and the scientific approach.

At the beginning of the lesson, the teacher presented contextual problems related to sequences and series. These contextual problems served as a starting point for students to observe patterns, understand situations, and connect daily experiences with mathematical concepts. This activity reflects the RME principle that places real-life contexts as the basis for forming mathematical concepts. Through observation activities, students were guided to identify important information, recognize patterns, and understand problems before formulating problem-solving strategies.

In the next stage, students engaged in questioning and discussion activities. Students were given the opportunity to ask questions, share initial hypotheses, and discuss problem-solving strategies in groups. Group discussion activities are important because they allow students to compare ways of thinking, explain ideas, and build understanding through interaction. In RME learning, interaction among students and between students and teachers is a key principle because mathematical understanding develops through the negotiation of meaning and exchange of strategies.

Next, students carried out experimenting and reasoning activities through the Student Worksheets LKS. At this stage, students solved contextual problems, constructed mathematical models, identified patterns, and drew generalizations. For example, in sequences, students were guided to find the pattern of sequence terms from real-life situations and then connect it to the general form of the sequence. In series, students were guided to understand the meaning of summing terms through the given context. This activity helps students understand that mathematical formulas are not merely rules to memorize but are the result of thinking and generalization processes.

In the final stage, students communicated the results of their discussions through presentations or explanations in front of the class. Other groups were given the opportunity to respond, ask questions, or compare problem-solving strategies. The teacher then facilitated students in formally concluding mathematical concepts. This stage demonstrates the connection between students' informal activities in solving contextual problems and the formation of formal mathematical concepts. Thus, the learning activities in this study include the scientific stages of observing, questioning, experimenting, reasoning, and communicating.

Table 2 Relationship between learning activities, scientific approach, and RME principles

Learning stage	**Student activities**	**Scientific approach component**	**Observable RME principle**
Presentation of contextual problems	Students read, observe, and understand problems related to sequences and series	Observing	Use of real life context
Identification of information and questions	Students ask questions and present initial hypotheses	Questioning	Knowledge construction by students
Group discussion through LKS	Students collaborate to formulate problem-solving strategies	Experimenting / Collecting information	Student interaction and contribution
Modeling and generalization	Students identify patterns, construct models, and draw conclusions	Reasoning / Associating	Horizontal and vertical mathematization
Presentation of discussion results	Students explain their work and respond to other groups	Communicating	Classroom interaction and reflection
Concept conclusion	Students and teacher formulate formal concepts of sequences and series	Communicating and concluding	Connection between context and formal concepts

Based on Table 2, the implemented learning activities reflect an integration of the scientific approach and RME principles. Students are not directly given formulas; instead, they are first guided to understand problems, observe patterns, discuss, develop strategies, and communicate results. This process shows that the developed learning materials effectively encourage active student engagement during learning.

The learning activity section can also be reinforced with photographic documentation of the learning process. Photos should be selected from sessions and post-tests that best represent the learning process, such as group discussions, use of LKS, presentation of work results, and evaluation activities. These photos can be presented as Figure 2.

(a) (b)

(c)

(d)

Figure 2 Learning activities during the implementation of RME-based mathematics learning devices with a scientific approach: (a) students observe contextual problems, (b) students discuss and complete worksheets in groups, (c) students communicate mathematical ideas, and (d) students complete the post-test

Pedagogically, the learning activities observed in this study demonstrate a strong alignment between RME and the scientific approach. RME provides the foundation for learning through context and student construction of concepts, while the scientific approach provides a systematic structure for learning activities. Both complement each other in creating mathematics learning that is active, contextual, and meaningful. These findings align with Freudenthal and Gravemeijer, who emphasized the importance of context, modeling, and student activities in mathematics learning [7,8]. In addition, these results are consistent with studies on activity-based learning, which show that student engagement in the learning process can enhance understanding and learning outcomes [13,14].

3.3. Practicality of Learning Materials

The practicality of the learning materials was analyzed based on teachers' ability to manage learning and students' responses to both the learning process and the materials used. Practicality is important to show that the developed materials are not only theoretically valid but can also be used effectively in classroom learning. Practical learning materials must be easy for teachers to understand, applicable within the allocated time, support student activities, and receive positive responses from students.

Observation results showed that teachers' ability to manage learning reached 96.23%, which falls into the very good category. This indicates that teachers could conduct learning according to the scenarios designed in the RPP. Teachers were able to start the lesson with contextual problems, guide students in group discussions, provide prompting questions, facilitate presentations, and assist students in concluding mathematical concepts.

In addition to teachers' abilities, student responses are also an important indicator of the practicality of the materials. Positive student responses to the learning process reached 96.76%, while positive responses to the learning materials reached 89.35%. These results indicate that students responded well to RME based learning with a scientific approach and to the materials used, particularly the LKS and learning activities that guided them to learn through real life contexts.

Table 3 Practicality result of learning materials

No.	Practicality indicator	Percentage	Category
1	Teacher's ability to manage learning	96,23%	Very Good
2	Positive student response to learning	96,76%	Very Good
3	Positive student response to learning materials	89,35%	Very Good

Based on Table 3, all practicality indicators fall into the "very good" category. The high teacher ability indicates that the materials can be used operationally in learning. Positive student responses show that the learning process was well received and provided an engaging learning experience. This is important because good learning materials must not only be theoretically sound but also support students' comfort, engagement, and participation.

The practicality of these materials is closely related to the characteristics of RME and the scientific approach. Learning that starts from real-life contexts helps students understand the usefulness of the material. Group discussions and the use of LKS make students more active in solving problems. Presentations also help train students to communicate mathematical ideas. Thus, the practicality of the materials is demonstrated not only by teachers' ease of teaching but also by students' engagement in the learning process.

These findings support the view that good learning materials must meet practical criteria, meaning they can be used by teachers and accepted by students in real learning situations [12]. Furthermore, these results align with previous studies on learning development, which show that materials based on activities, context, and collaboration can increase student engagement and elicit positive responses to learning [15–18].

3.4. Effectiveness of Learning Materials on Learning Outcomes

The effectiveness of the learning materials was analyzed based on students' learning outcomes in the experimental and control classes. The experimental class received learning using RME-based materials with a scientific approach, while the control class received conventional learning. Effectiveness was evaluated by comparing the average posttest scores, t-test results, and N-Gain values.

The posttest results showed that the experimental class had an average score of 84.3, while the control class had an average score of 72.5. The mean difference of 11.8 indicates that students participating in RME-based learning with a scientific approach achieved higher learning outcomes compared to students receiving conventional learning. This demonstrates that the developed learning materials had a positive impact on students' understanding of sequences and series.

Table 4 Comparison of learning outcomes between experimental and control classes

No.	Learning outcome indicator	Experimental Class	Control class
1	Average Posttest Score	84,3	72,5
2	N-Gain	0,68	0,42
3	N-Gain category	Medium	Medium

Based on Table 4, the experimental class had higher posttest scores and N-Gain values than the control class. The N-Gain for the experimental class was 0.68, while the control class was 0.42. Although both fall into the "medium" category, the improvement in the experimental class was higher than that of the control class. This indicates that RME-based learning with a scientific approach is more capable of improving students' learning outcomes than conventional learning.

Table 5 T-test result of posttest scores for experimental and control classes

No.	Statistical Test Component	Value
1	t-value	7,21
2	Significance	0,000
3	Significance level	0,05
4	Decision	Significant difference exists
5	Interpretation	RME based learning with a scientific approach is more effective than conventional learning

In addition to descriptive analysis, the effectiveness of the materials was also tested using a t-test. The t-test results showed a t-value of 7.21 with a significance value of 0.000. Since the significance value is less than 0.05, there is a significant difference in learning outcomes between the experimental and control classes. Thus, the developed learning materials can be considered effective in improving students' mathematics learning outcomes on sequences and series.

These effectiveness results indicate that RME-based learning materials with a scientific approach can provide a better learning experience for students. The improvement in learning outcomes in the experimental class can be explained by the characteristics of the learning implemented. First, learning starts from contextual problems, making it easier for students to understand the meaning of concepts. Second, the LKS allows students to explore patterns and formulate problem-solving strategies. Third, group discussions enable students to build understanding through interaction. Fourth, presentations and conclusions help students connect the results of activities to formal mathematical concepts.

These findings align with Freudenthal's idea that mathematics should be learned as meaningful human activity [7]. In this study, students did not merely receive formulas for sequences and series; they were actively involved in discovering and understanding concepts through activities. The results also support Gravemeijer's view that using context and models helps students move from informal to formal understanding [8].Thus, the improvement in learning outcomes in the experimental class can be understood as the result of more active, contextual, and structured learning.

The effectiveness of learning is also related to the scientific approach. The stages of observing, questioning, experimenting, reasoning, and communicating provide a learning structure that allows students to develop understanding gradually. When students observe contextual problems, they begin to build initial understanding. When they ask questions and discuss, they develop critical thinking. When they experiment and reason, they construct models and generalizations. When they communicate results, they strengthen understanding and correct conceptual errors. This process contributes to the increased learning outcomes of students.

3.5. Relationship Between Validity, Learning Activity, Practicality, and Effectiveness

The results of this study indicate that the quality of learning materials cannot be understood from a single aspect. Validity shows that the materials have a strong content and construct foundation. Learning activity demonstrates that the materials can encourage students to be active in the learning process. Practicality indicates that the materials can be implemented by teachers and accepted by students. Effectiveness shows that the materials have a positive impact on students' learning outcomes.

These four aspects are interrelated. Valid materials provide a strong foundation for conducting learning. Well-designed materials enable teachers to manage learning effectively. Properly implemented learning encourages students to actively observe, question, discuss, reason, and communicate. Active and meaningful learning activities then contribute to improved student learning outcomes. Thus, the effectiveness of learning in this study does not stand alone but is the result of the integration of tool design, learning activities, and classroom implementation.

3.6. Research Limitations

Although the results show that the developed learning materials are valid, practical, and effective, this study has several limitations. First, the implementation of the materials was conducted in a single school, SMA Negeri 1 Dringu, so generalizing the results to other schools should be done with caution. Second, the material used was limited to sequences and series, so the effectiveness of the materials on other mathematics topics still needs further testing. Third, the observation of learning activities was conducted during the implementation in the experimental class, so the results were highly influenced by classroom conditions, student characteristics, and teachers' ability to manage learning.

4. Conclusion

This study produced mathematics learning materials based on Realistic Mathematics Education (RME) with a scientific approach on the topic of sequences and series, including Lesson Plans (RPP), Student Worksheets (LKS), and Learning Outcome Tests (THB). Validation results showed that the materials were in the "very valid" category, with validation percentages of 91.30% for RPP, 90.18% for LKS, and 91.03% for THB. The implementation of learning also showed that students were actively engaged in observing contextual problems, discussing, formulating problem-solving strategies, communicating results, and drawing mathematical conclusions.

The developed materials met the criteria for practicality, demonstrated by teachers' ability to manage learning at 96.23%, positive student responses to learning at 96.76%, and positive responses to the materials at 89.35%. In terms of effectiveness, the experimental class achieved an average posttest score of 84.3, higher than the control class's 72.5, with N-Gain values of 0.68 compared to 0.42. The t-test results showed a t-value of 7.21 with a significance of 0.000, indicating a significant difference in learning outcomes between the two classes.

Thus, RME-based mathematics learning materials with a scientific approach are valid, practical, and effective, and can support active, contextual, and meaningful student learning activities. This study contributes to the development of mathematics learning that focuses not only on the product of the materials but also on the quality of learning activities and improvements in students' learning outcomes.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no financial or non-financial conflicts of interest that could influence the conduct of the research, data analysis, or preparation of this article.

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