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The Development of STEM-Based Science Teaching Materials on Simple Electrical Circuit Materials

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Abstract

This study aims to create STEM-based science teaching materials based on simple electrical circuits and determine the feasibility of STEM-based teaching materials. Research and development of the Dick & Carey model is the type of research used. The research process comprises four stages: needs analysis, product design, validation and evaluation, and testing. Material experts, presentation experts, linguists, and graphic experts are all involved in expert validation. Teachers who teach science subjects participate in the product feasibility test. Individual, small group, and field trials assess students' readability. Expert validation revealed that the content aspect was 97.7 % with a very decent category, the presentation aspect was 97.7% with a very proper category, the language aspect was 85% with a very decent category, and the visual aspect was 80 percent with a worthy category. The science teacher's feasibility test results showed that the content aspect was 90 % with an excellent category, the presentation aspect was 98.6% with an outstanding category, and the language aspect was 96.7% with a superior category. Students' readability test results showed an average score of 87.7% in the excellent category. Based on the validation and legibility trials findings, developing STEM-based science teaching materials (Science, Technology, Engineering, and Mathematics) on simple electrical circuit materials is feasible. It can be used as a learning resource.

Keywords: teaching materials, STEM, simple electrical circuit materials

INTRODUCTION

Learning the natural sciences, often known as science, is crucial to maintaining daily life since it strategically enhances the calibre of human resources. Science is concerned with how to acquire information about nature methodically. Therefore it is a process of discovery and the mastery of a body of knowledge in the form of facts, concepts, or principles (Yuliani, Cahyani & Roviati 2016).

Science education strongly emphasizes fostering practical skills so students can scientifically investigate and comprehend their world. The scientific method allows for the sequential and systematic approach needed to solve problems in science. Understanding science concepts is based on products, practices, and scientific attitudes (Trianto 2011) (Izzuddin 2019). This is undeniable because science is viewed as a systematic body of ideas that often addresses natural events that emerge through the scientific method, which includes testing and observation, and necessitates scientific characteristics like curiosity, openness, and honesty (Shepa & Uskenat 2021), (Nastiti & Hinduan 2012).

According to the needs analysis conducted on the students, 60% felt that the teaching materials could have been more appealing in terms of look and design, making them less eager to study them. As many as 63% of students complained that the book's contents and instructions were not described at the outset. 53% of students said that the offered content needed more sequential. Up to 60% of students claimed that some sections of the book's presentation of the information were difficult to understand because the language employed needed to be more communicative. Using various learning resources is one of the efforts that can be made to provide the best learning for students. The availability of learning resources will aid the learning process in understanding objectives. Learning resources can take the form of information presented in various forms of media that can help students improve their learning outcomes (Henukh, Loupatty & Supriyadi 2022). Students may become more interested in participating in the learning process if multimedia is used in the classroom. Texts, images, and tables are all part of teaching materials, which are a type of learning multimedia (Henukh et al. 2020)

Teaching materials are any materials used to assist teachers or instructors in teaching and learning activities in the classroom. Teaching materials can also communicate information, concepts, and knowledge that are easily understood by educators and students (Kesumawati 2014). Teaching materials must be created because they can assist teachers in delivering material. The learning process will run more smoothly if it makes the most of the teaching material to assist students (Henukh et al. 2019), (Habibi 2014).

Teaching materials may include problems from everyday life that require students to experiment and present data creatively. Teaching materials can be created by combining scientific literacy dimensions with assignments or activities that give engaging illustrations or pictures. Students learn to connect the material learned in class with the context of their lives and the link between science and technology, so school learning is informative but also practical and helpful. One of the goals of studying science is to discover the relationship between science, technology, and society (Chiapetta & Koballa 2010) (Astra, Aminudin & Henukh 2021).

The quality of teaching materials is critical in facilitating effective learning. Suitable teaching materials have the following characteristics: self-instruction, which allows a person to learn independently without relying on others; All required learning materials are contained in the teaching materials, making them self-contained. The characteristics of teaching materials are independent of other teaching materials/media; Adaptable teaching materials should be highly adaptable to advances in science and technology. Every instruction and information display appears beneficial and friendly to the wearer (Lestari 2013), (Daryanto 2013).

The effectiveness of learning is dependent on the quality of teaching materials. The quality of learning suffers when educators are only focused on existing teaching materials and lack the creativity to develop innovative teaching materials. Teaching materials must be developed to help teachers deliver content and meet learning objectives (Bybee 2010).

A design and redesign process (engineering design process) in STEM learning encourages students to produce their best products. The findings of Becker's research show that incorporating STEM aspects can positively impact student learning, particularly in increasing learning achievement in science and technology (Becker & Park 2011). STEM education teaches students how to use concepts, principles, science, technology, engineering, and mathematics (STEM) concepts in an integrated manner to create products, processes, and systems that benefit human life (Yuanita & Kurnia 2019). Students in STEM learning require assistance in acquiring relevant scientific or mathematical ideas in the context of engineering or technology design, productively relating those ideas, and rearranging their ideas to reflect normative ideas and practices, scientific ideas and practices (Honey, Pearson & Schweingruber 2014).

According to Chingos and Whitehurst (Chingos & Whitehurst 2012), the choice of teaching materials has a more significant impact on student learning than the effectiveness of educators in the classroom. The interaction between educators and students is governed by teaching materials provided by schools and the government, so developing teaching materials in the science curriculum in schools is essential (Kesidou & Roseman 2003). STEM-integrated learning can only function if STEM-integrated science teaching materials are developed.

As our reliance on technology and science grows, creating STEM-based educational resources is more crucial than ever. Given how quickly technology is developing, students must receive a solid

STEM education to prepare them for jobs in these areas (Shernoff et al. 2017). Students can learn about cutting-edge technologies and scientific ideas and acquire valuable hands-on experience in subjects like engineering, computer science, and biology by incorporating STEM-based teaching materials into the curriculum (Wang et al. 2020). Students' critical thinking and problem-solving abilities can be enhanced with the aid of STEM-based teaching materials, which are crucial for success in any profession. Students gain the ability to approach issues methodically, use evidence to support their claims, and effectively convey their ideas by working through STEM challenges and projects. Because STEM learning can address the issue of multidisciplinary science, it becomes a learning model for the present era of globalization (Astuti, Rusilowati & Subali 2021).

Based on the data obtained from the needs analysis, the class VI science book contains material: Development of Living Things, Adaptation of Living Things, Electrical Circuits, Magnets, Saving Electrical Energy, Solar System, and Earth and Moon Movement. Of the seven materials in the book that are difficult for students to understand, they are 66% Electric Circuits, 13% Electrical Energy Saving, 7% Magnets, 7% Solar System, and 7% Motion of the Earth and Moon.

The available electrical circuit teaching materials still need to be refined according to input from the teacher. Therefore the authors develop teaching materials on the subject matter of electrical circuits with some novelty by integrating STEM learning.

METHODS

The research model used in this study is research and development through four major stages based on Dick and Carey's research and development (Trianto 2017). The Dick and Carey Model's stages are divided into ten steps, including: Identify Instructional Goals, Conduct Instructional Analysis, Analyze Learners and Contexts, Write Performance Objectives, Develop Assessment Instruments, Develop an Instructional Strategy, Develop and Select Instructional Materials, Designing and Conducting Formative Evaluation of Instruction, Revise Instruction, dan Design and Conduct Summative Evaluation.

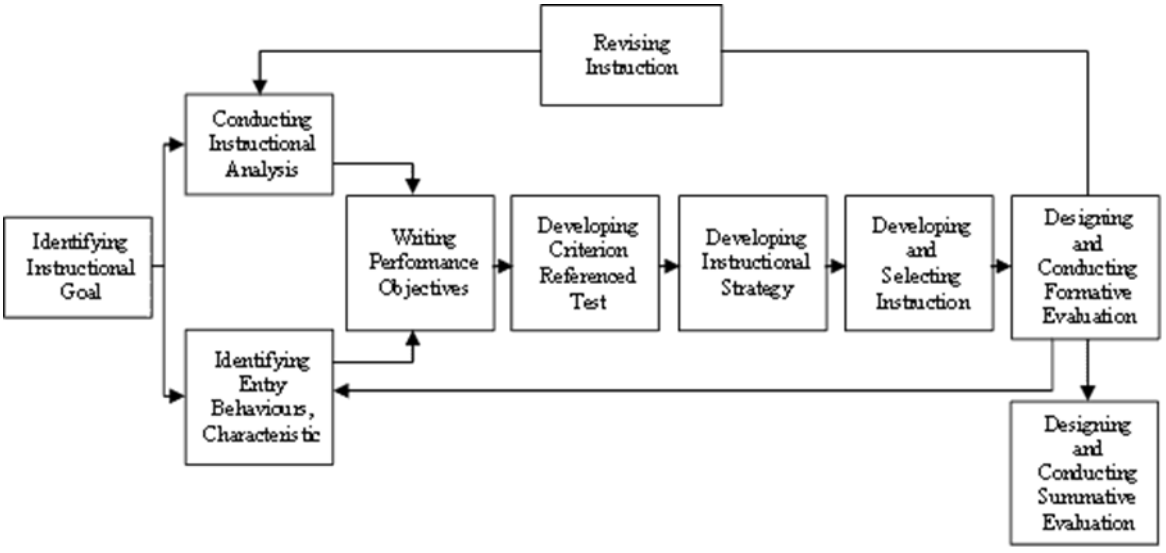


FIGURE 1. The Dick and Carey Systems Approach Model (D'Angelo, Bunch & Thoron 2018)

This research uses four significant stages of dick & Carey; there is 1) the Needs Analysis Phase; 2) the Product Design Stage; 3) the Validation and Evaluation Phase, and 4) the Final Product Stage. This study's four stages of development were carried out following product development procedures. First, the Needs Analysis Stage reviews the developed product to prepare the initial draft based on field needs. The final product will be teaching materials in textbooks for teachers and students. Researchers conducted literature reviews, curriculum analyses, and field studies involving teacher observations and student questionnaires.

Second, the Product Design Phase entails developing learning tools and designing STEM-based science books. Third, the validation and evaluation stages are crucial in determining the validity and quality of a product to be manufactured. Material experts, presentation experts, linguists, and graphic experts perform the expert validation stage to gather feedback and suggestions. Expert input and suggestions are used to improve the parts that have been criticized and the products that have been developed. The next stage is a science teacher feasibility test to determine whether the developed book can be used as teaching materials in the field. The next series of validation and evaluation stages is the readability test stage for students as potential users. Fourth, Improvements made based on input at the validation stage resulted in a final product in the form of a book.

The application of the STEM approach in the developed teaching materials is described in the following TABLE 1.

TABLE 1. The application of the STEM approach in the developed teaching materials

STEM Approach	Description of the application of the STEM approach in the developed teaching materials
Science	The invitational phrases "Let's Learn," "Let's Observe," and "Let's Talk" are used to introduce different aspects of science as a concept and research process. Let's Learn encourages literacy activities by helping people understand science concepts and content. Students are encouraged to conduct easy experiments or experiments to better grasp ideas or concepts in Let's Observe. Let's Talk includes issues about ideas being examined and cooperatively resolved in groups.
Technology	Using the phrase "Let's Find Out," discuss how science is applied in several technology areas. Students are invited to research this assignment using print or digital media.
Engineering	The invitational phrase "Let's Do the Project" is used in the engineering component of scientific engineering. Students participate in this activity by performing tasks to create something that will help them or others. Activities for applying knowledge and solving problems are included in the activities.
Mathematics	With the phrase "Let's Count," discuss various mathematical concepts. Students engage in this exercise by analysing the data collected, drawing conclusions, and communicating.

The following calculations were used to determine the percentage of success: (Lestari et al. 2017), (Uskenat, Iswanto & Indrasari 2021).

$$P = \frac{S}{N} \times 100\% \quad (1)$$

P denotes the percentage of success (%), S is the number of scores, and N is the maximum scores.

TABLE 2. Score Interpretation

Score	Interpretation
81% - 100 %	Very Appropriate
61% - 80 %	Appropriate
41% - 60 %	Appropriate Enough
21% - 40 %	Less Appropriate
1% - 20%	Not Feasible

The fourth stage is the final textbook of STEM-Based Science teaching materials (Science, Technology, Engineering and Mathematics).

RESULTS AND DISCUSSION

The product was obtained through the Dick and Carey research and development stage model using STEM-based science teaching materials on simple electrical circuits.

Needs Analysis Stage

Reviewing the 2013 Curriculum syllabus on electrical circuit material by the guidelines in "Core Competence (KI) and Basic Competence" allowed for the analysis of the natural science content. Interviews were conducted with grade VI educators, and it obtained data that educators did not develop their teaching materials but used teaching materials developed by a team of teachers. Where the teaching materials used needed to be perfected because the material was too dense, there were too many practice questions, and the book presentation was less attractive. The electrical circuit is regarded as rigid material as well. Class VI students were given the questionnaire to complete, and 30 respondents were randomly chosen to participate. The science education materials' display data was discovered to be less appealing, the book's contents and instructions were not provided, the material was not given in order, the drawings and illustrations were less appealing, and the language was less comprehensible. According to (Kumar 2017), teachers must follow the curriculum and provide a better platform to understand the curriculum with the help of materials. Teachers may adapt, supplement, and elaborate the materials to disseminate the content to the students, and they need to monitor the student's progress and evaluate the students. The production of teaching materials is carried out by incorporating STEM disciplines into it using the results of the needs analysis.

Product Design Phase

The researcher created the syllabus and Learning Implementation Plan using the KI, KD, and Competence Achievement Indicators at this point. Afterward, provide instructional materials and practical validatioetical validation tools. This is the opinion (Kumar 2017), which states that any syllabus or curriculum has the goal of learning. Therefore, educators make devices according to the existing syllabus.

Overview of the Product

The teaching material model developed consists of 27 parts, namely, the front cover, initial page, introduction, table of contents, list of pictures, book instructions, concept map, title, introduction to the material, let us learn, let us observe, let us find out, did you know, let us practice, project assignments, let us discuss, let us analyze, let us reflect, let us count, let us think, summary, competency test, bibliography, glossary, index, author profile, and back cover. The following are examples of some of the displays of teaching materials that have been developed,

FIGURE 2. Examples of some parts of teaching materials that have been developed

Validation and Trial Test Results

The feasibility test is divided into two stages: theoretical feasibility and practical feasibility. Experts in their fields participate in theoretical feasibility tests, whereas teachers and students, as users of the developed product, participate in empirical feasibility tests. Using a checklist, the feasibility of teaching materials is tested theoretically with content/material experts, presentation experts, linguists, and

graphic experts. A questionnaire instrument was used to collect data for validity and trial purposes. The following table summarises the results of the validation and trial tests:

TABLE 3. Material Expert Validation Data

Aspect	Score	Percentage	Interpretation
Social attitude	10	100 %	Very Appropriate
Material Coverage	10	100 %	
Material Accuracy	19	95 %	
Compliance with Laws and Legislation	14	93.3 %	
Skill Coverage	20	100 %	
Average		97.7%	

The percentage of the average score for all aspects is 97.7%, based on the results of the content/material expert validation shown in TABLE 3. This score indicates that the teaching materials developed from the material aspect are "Very Appropriate" for field testing with revisions and suggestions.

Material experts' comments or suggestions are slightly revised in writing and language. Developers then revise the parts that have been given feedback. Here is an overview of the changes.

Before Revision

After Revision

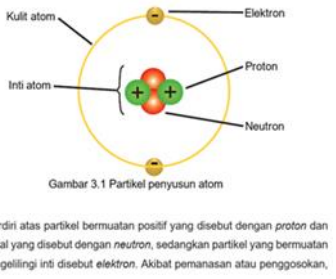
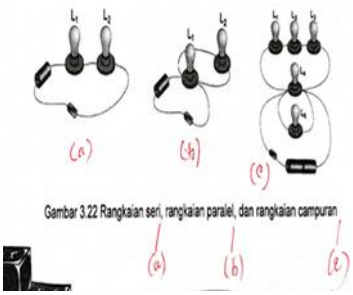


FIGURE 3. Adding atomic symbols

Before Revision



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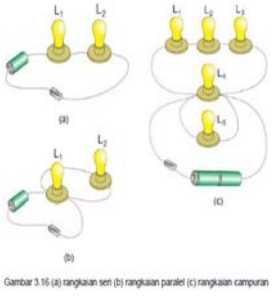
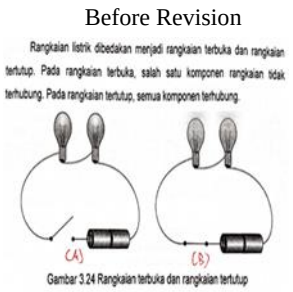


FIGURE 4. Added description of series, parallel, and mixed circuits

Before Revision



After Revision

FIGURE 5. Added description of open and closed circuit pictures

TABLE 4. Data Validation of Presentation Experts

Aspect	Score	Percentage	Interpretation
Presentation Techniques	14	93.3 %	Very Appropriate
Presentation Support	30	100 %	
Presentation of Learning	15	100 %	
Completeness of Presentation	39	97.5 %	
Average		97.7%	

The percentage of the average score for all aspects is 97.7 percent, based on the results of the presentation expert validation shown in TABLE 4. This score indicates that the presentation-related teaching materials were rated "Very Appropriate" and tested with revisions and suggestions.

According to presentation experts, the filling space for student evaluations should be enlarged, and the fonts should be consistent, allowing for empty pages. Developers then revise the parts that have been given feedback. Here is an overview of the changes made.

Before Revision

After Revision

FIGURE 6. Use of space

Before Revision

After Revision

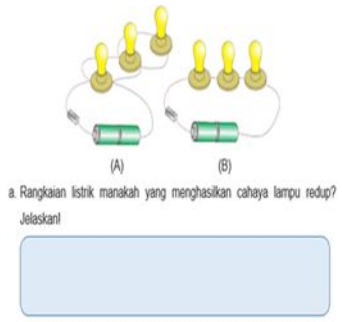


FIGURE 7. Adding space for doing tasks

TABLE 5. Validation of Linguists

Aspect	Score	Percentage	Interpretation
Conformity to the Development of Learners	9	90 %	Very Appropriate
Motivating Ability	4	80 %	
Conformity with Indonesian Language Rules	18	90 %	
Use of Symbols/Emblems/Terms	4	80 %	
Average		85%	

The average score for all aspects is 85 percent, based on the validation results of linguists shown in TABLE 5. This score indicates that the teaching materials developed from the language's appropriateness are rated "Very Good" and will likely be tested with revisions and suggestions.

Linguists advise that sentences should not be too long, that scientific language should be used rather than popular language, and that pictures should be drawn rather than scanned. Developers then revise the parts that have been given feedback. Here is an overview of the changes.

Before Revision

After Revision

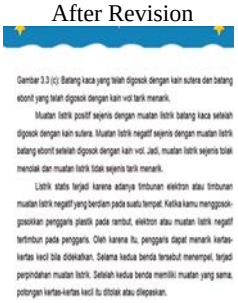


FIGURE 8. Using effective sentences

Before Revision

After Revision

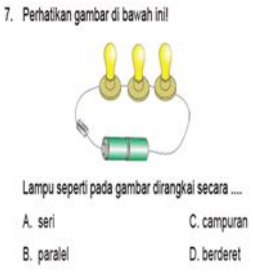


FIGURE 9. Replacing a picture of an electrical circuit that is less clear

Before Revision

After Revision

FIGURE 10. Replacing unclear project assignment drawings

TABLE 6. Data Validation of Graphic Experts

Aspect	Score	Percentage	Interpretation
Book Cover Design	16	90 %	Very Appropriate
Typography and Illustration	32	80 %	
Book Content Design	24	90 %	
Average		80%	

The average score for all aspects is 80 percent, based on the results of the graphic expert validation shown in TABLE 6. This score indicates that teaching materials developed from graphic feasibility are rated “Good” and should be tested with revisions and suggestions.

Graphic experts have suggested reducing the narrative/description to maximise interest and readability. Developers then revise the parts that have been given feedback. Here is an overview of the changes.

Before Revision

After Revision

FIGURE 11. Replacing unclear project assignment drawings

Before Revision

After Revision

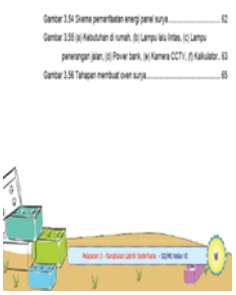


FIGURE 12 Tidy up the list of left-aligned images

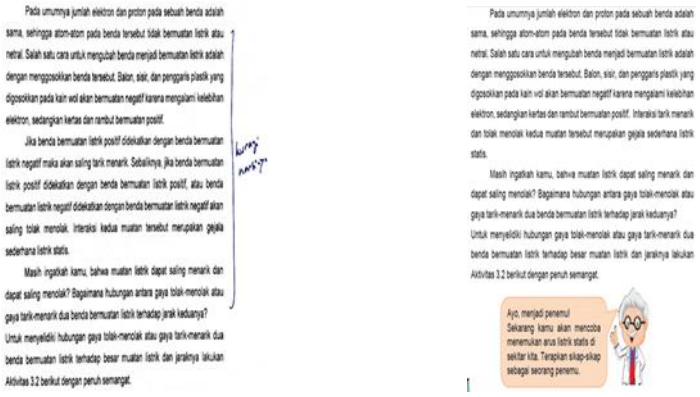


FIGURE 13 Reduce the description of the material

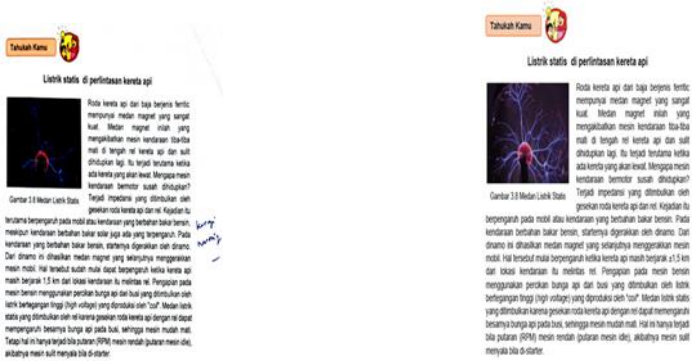


FIGURE 14 Reducing the description of "Did You Know"

TABLE 7. Science Teacher Validation Data

Aspect	Score	Percentage	Interpretation
Theory	45	90 %	Very Appropriate
Language	14.5	96.7 %	
Presentation	34.5	98.6 %	
Average		95.1%	

The average score for all aspects is 95.1 percent, based on the results of teacher validation shown in TABLE 7. This score indicates that the developed teaching materials fall into the "Very Good" category and are well suited for use as science learning media.

TABLE 8. Data on Individual Trial Results

Aspect	Score	Percentage	Interpretation
Theory	44.0	80 %	Appropriate
Language	11.7	77.78 %	
Presentation	24.0	80 %	
Average		79.26%	

The average score for all aspects is 79.26 percent, based on the results of individual trials shown in TABLE 8. This score indicates that the developed teaching materials fall into the "Good" category and can be used as science learning media.

TABLE 9. Small Group Trial Results in Data

Aspect	Score	Percentage	Interpretation
Theory	49.8	90.55 %	Very Appropriate
Language	13.5	90.00 %	
Presentation	27.6	92.00 %	
Average		90.85%	

The number of students in the small group trial was 10 people. The average score for all aspects is 90.85 percent, based on the results of the small group trial shown in TABLE 9. This score indicates that the developed teaching materials are in the "Very Good" category. The trial results show that STEM-based science teaching materials are ideal for use as learning media.

TABLE 10. Field Trial Result Data

Aspect	Score	Percentage	Interpretation
Theory	51.2	93.02 %	Very Appropriate
Language	13.8	92.00 %	
Presentation	28.2	94.00 %	
Average		93.01%	

The number of students in the field trial was 36 people. The average score for all aspects was 93.01 percent, based on the results of the field trials shown in TABLE 10. This score indicates that the developed teaching materials are in the "Very Good" category. The validation and field trial findings indicate that STEM-based science teaching materials are ideal for use as learning media.

The teaching materials were validated by material experts, Presentation experts, Linguists experts, and Graphic Experts. After the teaching materials were revised, the teaching materials were validated by two teachers to find out whether the printed learning resources developed could be used as alternative teaching materials in classroom learning activities. At this stage, the teacher implements learning using the learning documents that have been developed. After that, teaching materials were tried on students to get product feasibility input before further development and as a basis for revision before being developed to the field trial stage.

Product Design Phase

The final product in the form of teaching materials that have been tested is used as a product model that is ready to be implemented in the field.

CONCLUSION

Based on the due diligence of material experts, presentation experts, linguists, and graphic experts, an average score of 90.1% was obtained. The validation results from the teacher obtained a score of 90.1%, and an analysis of the readability of students was 87.7%. From these data, it can be concluded that the teaching materials developed are suitable for learning and can be used as learning resources.

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