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Scientific literacy on the topic of light and optical instruments in the innovation of science teaching materials

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Abstract: This study aims to innovate science teaching materials based on scientific literacy on light and optical instruments. The study used the research and development (R&D) method with the four-D (4D) model. The subjects in the study included three experts and 60 class VIII students with an age range of 13-15 years at the same level. This study collected quantitative data from product validation, questionnaire, and scientific literacy test. The questionnaire and test instrument have been proven valid and reliable based on expert judgment and empirical tests. The data were analyzed using descriptive and empirical statistic tests. The expert judgment proves that science teaching materials score 3.79 of 4 and scientific literacy aspects 3.71 of 4, which is valid. In addition, the teaching materials were also categorized as effective with an overall score (z = -4.731 and *p-value* = 0.000 < 0.05). In detail, the learning process increases student scientific literacy (*p-value* = 0.000<0.05). Furthermore, science teaching materials based on scientific literacy could be optimized to improve students' scientific literacy skills sustainably.

Keywords: Light and Optical Instruments, Scientific Literacy, Science Teaching Materials

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INTRODUCTION

Science learning is a process of forming knowledge that is arranged systematically and integrated related to natural phenomena and is obtained through a scientific process. In the context of learning, students must be able to make observations and experiments and understand a phenomenon scientifically or have sufficient scientific literacy skills (Rostikawati & Permanasari, 2016). Other facts show that science learning contains elements of application, process, scientific attitudes and mastery of good content and attitudes to make the right decisions. (Fahmi et al., 2021).

One of the concepts that students need to master in learning science is light and optical devices. The characteristics of this material are very related to student life both in the form of phenomena and technology. However, the facts show that students tend not to understand optical phenomena scientifically. The low learning achievement shows this in light and optical devices (Af'idayani et al., 2018; Rahayu et al., 2018; Putri et al., 2018; Fahmi et al., 2021; Yesinta et al., 2016).

Many things cause the low achievement of learning outcomes. One of them is the teaching material's presentation, so the learning process tends to be monotonous (Yasiro et al., 2020). Learning that is not interesting for students will make students tend to be lazy and not enthusiastic. Even though teachers pressure students to learn, the understanding that is formed does not occur naturally and will only impact short-term memory. Therefore, the demand to provide interesting and fun learning for students continues.

In science material, Zainab (2021) explained that the science learning process has more difficult challenges regarding teacher delivery and student acceptance. Many factors influence the difficulty of learning science, such as the concept of science being taught is still abstract (Laksamana, 2016), as in

light materials and optical devices. In context, it is easy for students to interact with light and optical devices, but conceptually students will have difficulty imagining it.

Student difficulties in understanding subject matter are challenging for teachers in preparing for the learning process. The teacher, of course, must try to recognize the characteristics of the material before teaching it to students so that the delivery process can run optimally (Rubini et al., 2018). The teacher can make efforts to study contextual physical symptoms and be around students so that learning becomes simpler and more meaningful (Fahmi et al., 2021). The concepts being taught must be simplified and based on contextual phenomena. Sukmawati (2016) emphasizes that the simpler the concept, the easier it is for students to understand the content properly.

The availability of alternative learning resources aims to make learning more effective, efficient, interesting and realistic (Olayinka, 2016). Teaching materials, an alternative learning resource, have several advantages, including 1) the concepts learned using teaching materials are clearer to students because these concepts are taught through learning activities, 2) students can participate creatively and think analytically when involved in learning, 3) encourage integration, work principles are learned, and with this teaching material students acquire problem-solving skills, attitudes, and scientific and technological knowledge (Akani, 2016).

Therefore, teaching materials must be designed based on strict criteria to facilitate students in achieving their learning objectives to the fullest. In developing teaching materials, teachers or practitioners must pay attention to the characteristics of students and teaching materials so that students can more easily understand the concepts presented during the learning process. It is easier for students to understand the teaching material because the delivery has been adjusted to the characteristics of students and the material.

Concept mastery ability is one of the fundamental abilities in learning science. Not only that, in various tests, the ability to master the concept is still an integral part. In scientific literacy, conceptual understanding is also integral (Sandi et al., 2014). In addition, Agustin et al. (2021) explain that ideal science learning can reflect a balanced scientific literacy domain. Nonetheless, the measurement facts show that students' ability to master concepts is still low and impacts low scientific literacy abilities. One reason is the availability of learning resources that support the mastery of scientific concepts and literacy. This causes students to misinterpret physical phenomena and identify concepts incorrectly (Rusilowati et al., 2016).

Literasi sains merupakan salah satu ranah studi Program for International Student Assesment (PISA). According to the Organization for Economic Cooperation and Development (OECD), scientific literacy is the ability to engage with science-related issues and scientific ideas as a reflective citizen. The success of learning science for students is achieved when students have good scientific literacy skills. But in fact, the results of the PISA survey regarding the level of scientific literacy place Indonesian students into a group of countries with low scientific literacy skills. In addition, an evaluation by the Trends in International Mathematics and Science Study (TIMSS) in 2018 also showed that Indonesian students were in the bottom 10 of all countries participating in the activity (OECD, 2019). Both of these assessments show that scientific literacy skills in Indonesia still need much improvement.

As an initial study, this research also made observations at SMPN Banjarmasin, South Kalimantan province, in class VIII. Preliminary observations showed that students often had difficulties understanding the material due to limited alternative learning resources, especially on light and optical devices. This result was confirmed by initial interviews with several science teachers who stated that the textbooks used in schools did not proportionally meet the scientific literacy category.

This fact was confirmed by the results of an analysis of science textbooks conducted by Asrizal et al. (2017), which shows that no specific textbooks guide students to learn scientific literacy sustainably. Another fact was put forward by Wahyu et al. (2014), which showed that the proportion of aspects of scientific literacy from textbooks with the highest category of scientific knowledge was only 46.3%. Therefore, it is necessary to develop integrated science teaching materials that train students' scientific literacy. In this study, our innovation focuses on providing alternative learning resources for light materials and optical devices. The competencies being trained to focus on scientific literacy skills.

Based on the facts and problems found, it is necessary to develop alternative learning resources, such as teaching materials based on scientific literacy, specifically on light and optical devices, to achieve learning objectives. Besides improving students' abilities, scientific literacy in teaching materials can also make them more easily interested in learning science, understanding its

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characteristics, and getting to know the environment through scientific processes and applying scientific concepts in real life.

METODE

Research design

This research is a type of Research and Development (R&D). This research aims to produce products, and teaching materials, that are valid and effective in learning. The development model that will be used in this study is the Four-D (4D) (Thiagarajan, 1974) model, which consists of 4 main stages: define, design, development and dissemination. In the trial phase, this study used a one-group pretest-posttest design.

Research Subject

This research was conducted on 60 students of class VIII SMP with a total population of 60 people. The students comprised 25 boys and 35 girls ages 13-15 years. The school that became the test site was a middle school category in Banjarmasin, South Kalimantan province. The selection of subjects took into account several aspects, such as the school environment's condition and location, the community's culture around the school, and the communication between researchers and science teachers.

Research Procedures

The initial stage in the Four-D (4D) model is Define (defining) to determine what products will be developed along with their specifications. This stage is carried out to analyze needs through research and literature studies. The next stage is Design (design) to make a design for a predetermined product. Furthermore, the Development stage is to make the design into a product and test the validity of the product repeatedly until the product is produced according to predetermined specifications. Then the Dissemination stage disseminates products that have been tested for the benefit of others (Thiagarajan, 1974).

This research was conducted by modifying the Four-D (4D) model to become Three-D (3D), as was done by Istyadji et al. (2022), who also modified the ADDIE model by only running until the implementation aspect because the conditions of the Covid-19 pandemic constrained the research implementation. Thus, researchers only carry out up to three stages, namely define, design, and development, as shown in Figure 1.

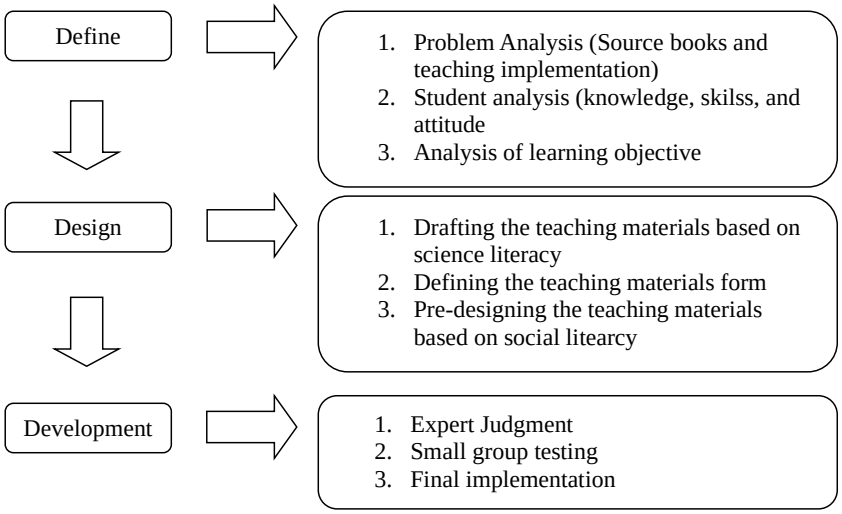

Figure 1. Modified Three-D (3D) Research Scheme of Four-D (4D)

Research Data Analysis Techniques

The research was carried out after the initial design or prototype of the teaching materials was compiled. After compiling the teaching material prototype, the next process is validating it by an expert or expert review. The validation results from the validator will be analyzed to analyze the feasibility of

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the product that has been developed. The questionnaire was arranged based on a Likert scale of 1-4 with details of 4 (good), 3 (enough), 2 (fair) and 1 (poor). (Sugiyono, 2015)

Criteria for the validity of teaching materials can be stated from the suitability of the preparation of teaching materials with the theory stated in the valid (proper) category or not. These results are based on the validator's assessment with three possible outcomes: feasible and ready to use, feasible but needs improvement, and not feasible. Components that need to be considered in the validation of teaching materials are; (1) format of teaching materials; (2) language; (3) content of teaching materials; (4) presentation; (5) benefits or uses; (6) aspects of scientific literacy. The assessment results are interpreted as in Table 1 (Widoyoko, 2016).

Table 1. Category of Teaching Material Assessment

Interval Skor	Kategori
$3.25 < x \leq 4.00$	Good
$2.50 < x \leq 3.25$	Enough
$1.75 < x \leq 2.50$	Fair
$1.00 < x \leq 1.75$	Poor

The review results are then converted into percentage intervals to suit the specified validity criteria. The eligibility criteria for teaching materials refer to Table 2 (Akbar, 2017).

Table 2. Criteria of Teaching Material

No.	Interval (%)	Criteria
1.	85.01- 100.00	Without revision
2.	70.01 - 85.00	Minor rev
3.	50.01 – 70.00	Major Revision
4.	01.00 - 50.00	Declined/Rejected

After the product was declared feasible by the expert, the research continued with the implementation of learning using scientific literacy-based teaching materials to see the effectiveness of the developed teaching materials. The study was conducted in 12 meetings for 4 weeks, with 10 lessons and 2 tests (pre-test and post-test). The test is carried out using a test instrument that can measure students' scientific literacy level. The test results were obtained from the initial test scores, and the final test in the intact class after learning was carried out with the developed teaching materials. Data from the test results were tested by testing the normality gain (n-gain) to determine the average increase in students' scientific literacy scores as a measure of learning effectiveness. The calculation of the gain score is based on the formula used by Hake (1998).

RESULTS AND DISCUSSION

Feasibility of Teaching Materials based on expert judgment

This study produces products in the form of teaching materials on light and optical tools based on scientific literacy that has been declared worthy of being experts. The results of the expert review show that the teaching materials meet the criteria of scientific literacy. This is based on the important points of teaching materials developed with the existence of sources of exploration and independent activities by students. Independent activities are designed to provide students with fun activities they can try immediately. Based on expert advice, the developed teaching materials can already be used in learning to train students' scientific literacy.

The teaching materials developed are printed teaching materials equipped with text or illustration formats, pictures, and discourses and phenomena that occur in everyday life. This can help students describe learning to be more contextual so that learning becomes meaningful. Contextual learning is also useful so that the concepts presented in teaching materials become simpler and easier to visualize. This solution refers to Sutardji's explanation (2010) that students' thinking skills are low due to not understanding the meaning of a lesson. The results of Laksamana's research (2016) explain that the characteristics of science material tend to be abstract, so the teacher must make this phenomenon concrete through contextual learning. The results of the expert assessment are shown in Table 3 below.

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Table 3. Teaching Material Validity

No.	Aspects	Score	$\bar{x}$	%	Category
1.	Format	101	3.74	94%	Without revision
2.	Language	203	3.75	94%	Without revision
3.	Content	98	3.62	91%	Without revision
4.	Presentation	218	3.82	96%	Without revision
5.	Benefit	24	4.00	100%	Without revision

The research expert's assessment results showed that the teaching materials developed were included in the valid category without revision. This can be seen through aspects that have been measured, such as the format of teaching materials, language, contents of teaching materials, presentation, benefits or uses of teaching materials, and elements of scientific literacy assessment. Based on the data in Table 3, the teaching materials that have been developed show a percentage of 95% with a valid category without revision in terms of the format of the teaching materials, language, content of teaching materials, presentation and benefits and uses of teaching materials. The average value of each aspect is 3.79, with a very good category. Based on these results, the teaching materials developed have met the eligibility standards to be applied in learning. Teaching materials that have been validated are then made minor improvements to get a better prototype.

Teaching materials are considered to stimulate dialogue and interactive skills. The language presented is straightforward. Teaching materials are arranged with coherence, the flow of thought and consistency, following the rules of good and correct Indonesian—consistently using terms and symbols or emblems. The assessment of the aspects of the content of this teaching material, including the coverage of the material, the accuracy of the material, and the sophistication, were considered very good. Presentation aspects include presentation techniques, conceptual coherence, support for the presentation of material, and presentation of learning in student teaching materials which are also considered very good. The aspects of the benefits or usefulness of teaching materials that are assessed include two criteria: they can be used as a guide for teachers in learning and can be used as a guide for students to study independently.

This study's results align with the opinion of Listianingrum et al. (2022), which states that in addition to considering the conditions of students and materials, teaching materials must be presented in attractive and simple language. This result follows the objectives of developing teaching materials as alternative learning resources, meaning that teaching materials must help students understand learning down to the technical realm. The format of teaching materials must meet eye-catching elements so that students can easily read, describe, and find information in teaching materials. These findings differ from textbooks generally intended for all ages and are designed in the most common forms, such as ISO standards.

The language aspect is also important in presenting alternative learning resources. One of the causes of students not understanding textbooks is that the language used is too formal and not friendly. Teaching materials, as alternative learning resources, allow it to be designed using more friendly language and adapting to the terms that apply in the area. It will cause the students to feel that teaching materials are more comfortable to read. Language, as a messenger, greatly influences the interest and motivation of readers. That is, the presentation in a simpler language is under the development of the student's environment. Teaching materials will become more interesting and increase student motivation to learn.

The content aspect is a very important part. This is because the content of teaching materials is the main message to be presented. In this study, the contents of teaching materials were presented using a different approach from that in textbooks because they were adapted to the conditions of the students. Content adjusted to the level of student development will make it easier for students to learn the material because they feel not burdened. Learning content that has been didactically reduced must be presented properly. In this teaching material, the presentation of content is made dynamic and adapted to the students' characteristics.

Feasibility of Teaching Materials based on Science Literacy Competence

The next teaching material feasibility test refers to scientific literacy competencies. The validation results of the developed teaching materials aim to determine aspects of scientific literacy in teaching

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materials on light and optical devices (Chiapetta et al., 1991; Asrizal et al., 2018). The results of the analysis of the validation of aspects of scientific literacy by the three validators on the developed teaching materials can be seen in Table 4.

Table 4. Feasibility of Teaching Materials based on Competences

No.	Aspects	Score	$\bar{x}$	%	Category
1.	Science as a Body of Knowledge	36	4.00	100%	Without revision
2.	Science as a Way to Investigate	23	3.83	96%	Without revision
3.	Science as a Way of Thinking	22	3.67	92%	Without revision
4.	Interaction of Science Technology and Society	10	3.33	83%	Without revision

Based on the data in Table 4, the results of validating the aspect of scientific literacy in teaching materials are 95% in the valid category without revision. The average value of aspects obtained is 3.71, with a very good category. These results also indicate that the aspects of scientific literacy in the teaching materials that have been developed meet the eligibility standards to be used as support in the learning process.

The aspect of science as a body of knowledge includes the presentation of facts, concepts, and principles that are in accordance with the material in the teaching materials that have been developed. One of the stimuli presented in teaching materials is "*shadows can be observed through images of ping pong balls behind which there is a boundary (wall) which is given light from a light source (flashlight)*." Another stimulus presented in the teaching materials is in the form of questions such as, "*have you ever observed how you are when you stand in front of a mirror and against a wall? Do you realize why you can see your reflection and your reflection on the wall?*"

Assessment of aspects of science as a way to investigate includes questions on evaluation and competency tests which contain questions through the use of the material in teaching materials that are adapted to aspects of student knowledge and are structured based on indicators of scientific literacy. In addition, teaching materials also provide supporting features to fulfill aspects of assessment that involve students in experiments or thinking activities through the "*let us try this*" feature and student worksheets. This test feature and activities in student worksheets function to practice observation skills, collect data, to find facts in conclusion. One of the activities in this trial feature is to observe the appearance of a coin placed in a glass before being filled with water and then slowly filled with water.

Assessment of aspects of science as a way of thinking has criteria for describing how a scientist experiments. One of the examples presented in this teaching material is the availability of information about how a scientist discovers infrared light through his experiments. This scientist was named William Herschel in the range of the 18th century.

The next validated aspect is the availability of discussion space presentation of facts and evidence related to the material presented. This aspect has been fulfilled through the let us discuss feature. This feature provides a discourse that contains problems that need to be analyzed to provide solutions through scientific methods. One of the discourses presented was that students were asked to provide a scientific explanation of the rainbow phenomenon.

This feature serves to assist students in practicing their thinking process skills. This is in line with the expression of Eggen and Kouchak (2012), who states that students' thinking skills will improve the more they study a topic. Therefore, students abilities will improve the more often they are faced with problems that need to be analyzed on an ongoing basis.

The criteria achieved in the interaction of science, technology and society are that there is an explanation of science and technology for the community through information-knowledge features and the use of optical devices that utilize the working principles of the properties of light, mirrors and lenses. One of the examples provided in teaching materials related to the interaction of science, technology, and society is that there is a thousand-image mirror vehicle as a tourist object for the community that takes advantage of the nature of light reflection on flat mirrors.

The availability of this aspect allows students to have the ability to use science in life in various events. The results of research by Agustini et al. (2013) and Afriana et al. (2016) showed that science, technology, and community learning models had improved students' skills in solving science problems in everyday life. The American National Science Teachers Association (NSTA) explains the interaction between science, technology and society as the basis of science education because it teaches interactive

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relationships between science, technology and society to make decisions in everyday problems. Elements of science, technology, and society are also interrelated to help students use science in technology to meet needs without damaging the environment (Rusilowati et al., 2015).

Based on the percentage of data recapitulation of the aspects of scientific literacy assessment which were validated by the three validators consisting of aspects of science as a body of knowledge, science as a way of investigating, science as a way of thinking, and the interaction of science and technology with society, it received a very good predicate with a validity of 95 % categorized as valid without revision. The scope of scientific literacy studied in this study refers to the literacy criteria in science textbooks (Chiapetta et al., 1991).

The Effectiveness of Scientific Literacy-Based Teaching Materials

This research was conducted in 12 meetings for 4 weeks. In the first meeting before learning, students are asked to do a pre-test with instruments that have been standardized to increase their validity and reliability. After that, in the next 10 meetings, learning was carried out using teaching materials based on scientific literacy that had been developed. At the 12th meeting, students returned to do a final test to see how far their level of thinking had increased, illustrating the effectiveness of the teaching materials being developed. Hadi (2016) explains that the development of teaching materials is categorized as effective if the teaching materials can achieve research objectives or have more value than pre-existing learning tools.

The added value of the developed scientific literacy-based teaching materials is that the presentation of the material is interactive and participatory (some sections invite readers to participate). The teaching materials developed can stimulate students to think more deeply and foster curiosity. Teaching materials present material descriptions, exercises, and case examples to encourage students to think deeply, as shown in Figure 2.

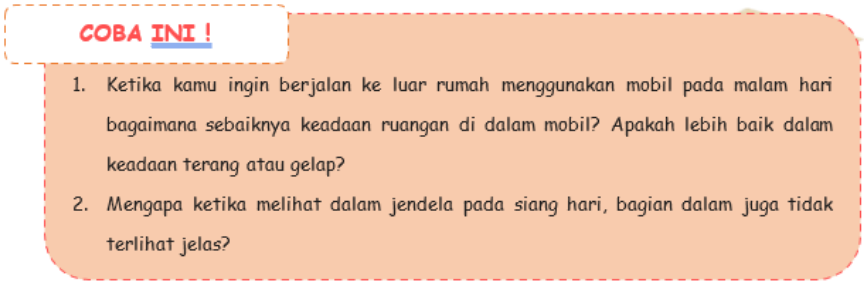

Figure 2. Study case in the Teaching Materials

Data on the results of tests for increasing scientific literacy skills in the initial and final tests are presented in full in Table 5.

Table 5. Students' Scientific Literacy

Aspect	Pre-Test	Post-Test	N-*Gain* (%)	Z-*Score*	P-*Value*
Overall	49,92	83,90	72,14	-4,731	0,000
Explaining Phenomena Scientifically	61,83	91,40	71,67	-4,274	0,000
Evaluating and Designing Investigative Efforts	64,52	91,94	72,04	-4,480	0,000
Scientific Interpretation of Data and Evidence	44,19	85,48	70,06	-4,815	0,000

Based on Table 5. it can be seen that learning using science literacy-based science teaching materials on the material of light and optical devices can show an increase in students' scientific literacy with an overall gain score of 72.14% in the high category. The Wilcoxon test is used to find out how the teaching materials used influence the increase in scientific literacy skills. The test results show that learning using scientific literacy-based science teaching materials on the material of light and optical devices has a significant influence on increasing students' scientific literacy abilities both as a whole and in terms of each aspect of their scientific literacy competence. This significant effect can be seen from the p-value, which is smaller than the z-score.

In the realm of scientific literacy, in the first indicator, students can provide an overview of facts about scientific phenomena and explain them with simple concepts that are easy to understand. These findings are in line with what Safitri et al. (2016) conveyed in their research, which shows that students

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with a good level of literacy can explain scientific phenomena and bring them into the learning process in the classroom.

The second indicator evaluates and designs investigative efforts. In this indicator, students can design simple research plans well. These findings are in line with what was conveyed by Yuliati (2017) and Lestari et al. (2021) in their research, which shows that those with a good level of literacy can formulate and evaluate their own beliefs and opinions in the form of research designs.

The third indicator shows the interpretation of data and scientific evidence. In this indicator, students who are the object of research can express their opinions with good arguments and accurate evidence. In line with this, Schwartz et al. (2006) explained that a person is said to have good scientific literacy if he can find out how to research, combine knowledge and facts, and express opinions with strong and accurate arguments.

Overall, this study shows that developing scientific literacy-based teaching materials on light and optical devices meets the criteria of high validity and effectiveness in achieving learning objectives. This is because learning by presenting impressions of scientific literacy in the classroom helps students learn real phenomena, reinforces conceptual understanding, and becomes a means to support their direct involvement in the learning process.

CONCLUSION

Scientific literacy-based teaching material innovation is an alternative that is highly recommended to continue to be carried out in order to achieve learning goals in schools. This is indicated by the validity data of the scientific literacy-based teaching materials developed, which are in the valid category without revision with a percentage of 95% with details of the validation results in terms of the format of the teaching materials, language, contents of teaching materials, presentation, and their benefits or uses. The results of validating aspects of scientific literacy in teaching materials obtained a percentage of 95% in the valid category without revision with details of the aspects assessed, namely science as a body of knowledge, science as a way of investigating, science as a way of thinking, and the interaction of science, technology and society. The effectiveness of the teaching materials developed is in a good category. This is shown by data on increasing scientific literacy skills as a whole ($z=-4.731$; p-value=0.000<0.05), as well as based on three indicators of scientific literacy separately (p-value=0.000<0.05). Scientific literacy-based research and learning need to be continued. There needs to be a joint effort to continue to develop scientific literacy-based teaching materials in science and general learning materials at the secondary school level.

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