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Development of STEM-Based Physics Learning Modules and Their Impact on Students' Scientific Literacy Skills

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Abstract: This research is a Research and Development (R&D) study that uses the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The purpose of this study is to develop a STEM-based physics learning module and test its validity, practicality and effectiveness in improving students' scientific literacy skills. Validation was conducted by three experts who assessed the module and the science literacy test. Ten physics teachers assessed the module's practicality. The effectiveness test was conducted using a quasi-experimental design with a posttest only control group design model in two classes, namely the experimental class (32 students) and the control class (31 students), both from SMAN 13 Takalar. The instruments used in this study were the validation sheet of the STEM-based physics learning module, the practicality sheet, and the validated students' scientific literacy ability test. The research findings revealed that the module was valid and suitable for use with a validity score of 0.80; teacher responses indicated that the module was very practical with an average score of 93.8%; and the t-test results showed that the average posttest score of the experimental class students was significantly higher than the control class, with a t-count value = 4.54 greater than t-table = 1.77 at a significance level of 5%. Based on these results, the STEM-based physics learning module is considered valid, highly practical, and effective in improving students' scientific literacy skills.

Keywords: Development; Physics learning module; Science literacy; STEM

Introduction

The 21st century is marked by rapid developments in various aspects of human life, including science and technology. The Industrial Revolution 4.0 is characterized by rapid advances in information and communication technology and increasingly complex future challenges (Yuliati & Saputra, 2019). Developments in science and technology have impacted global education. This has encouraged various countries to compete to continuously improve the quality of their human resources (Kasse & Atmojo, 2022). The provision of quality science education will impact a country's development. Science education depends on the learning methods used in each country. Through science education, students can engage with the impact of science on everyday life in society. By applying scientific concepts in science education, Indonesia is expected to be able to solve real-life problems in the 21st century. One of the essential competencies that every individual must possess to face the challenges of the 21st century is scientific literacy.

Scientific literacy is the ability to understand scientific concepts and processes and to use science to solve problems in everyday life (Nana, 2021). In the context of physics learning, this ability is still considered low in Indonesia. Physics education plays a crucial role in developing students' scientific literacy in the 21st century. The description of scientific literacy shows that when students learn scientific literacy, they can use scientific knowledge, identify questions, and draw conclusions based on evidence to understand and help

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make decisions about the natural world and human interactions with the environment (Ardiyanti et al., 2022). Building scientific literacy in the current generation does not mean making students into researchers, but rather building scientific and technological knowledge to play a role in determining choices that impact current and future survival (Ramli et al., 2022). Scientific literacy in physics learning is key to enabling students to understand natural phenomena scientifically and make decisions based on logical reasoning in everyday life (Husna et al., 2022).

Scientific literacy recognizes the importance of thinking and acting skills that involve mastering and using scientific thinking to recognize and address social issues (Januarti et al., 2024; Yuenyong & Narjaikaew, 2009). Scientific literacy is considered important because it can foster students' interest in understanding the environment, health, economics, social, and technology, and enable individuals to apply scientific knowledge, engage in decision-making, and address more complex real-world problems (Krapp & Prenzel, 2011; Mafarja et al., 2025; Susilawati et al., 2025). Scientific literacy enables students to feel more confident in dealing with issues that arise in everyday life related to science (Ploj Virtič, 2022). Therefore, measuring scientific literacy is important to determine students' scientific literacy levels in order to achieve good scientific literacy so that the quality of education in Indonesia can improve and compete with other countries (OECD, 2023). Since 2006, PISA has measured scientific literacy (Dreschel et al., 2011). However, the results of the 2022 Programme for International Student Assessment (PISA) international survey showed that Indonesian students' scientific literacy was relatively low compared to other countries. Indonesia ranked 64th out of 81 participating countries in the science aspect, with an average score of 383. Taskinen et al. (2013), stated that in order to achieve higher test scores, students should participate in learning STEM approaches. Furthermore Holmlund et al. (2018), stated that many countries face significant challenges in implementing STEM approaches in the classroom.

According to Yusmar et al. (2023), data analysis shows that Indonesian students' scientific literacy scores are low and have never reached the standard score set by PISA. This is in line with research conducted by Dhanil et al. (2023) which states that the urgency of mastering scientific literacy is currently increasing in the context of physics learning. Students who have scientific literacy skills will be able to apply the knowledge learned to solve problems in everyday life (Jufrida et al., 2019). Several factors contributing to the low scientific literacy of students in Indonesia include students not understanding basic scientific concepts, conventional physics learning, weak ability to interpret tables or graphs, and a lack of a culture of scientific reading and writing. As a result, physics lessons are often considered difficult because they are only synonymous with memorized formulas and theories (Aprilia et al., 2022). This is in line with the results of observations conducted at SMAN 13 Takalar, which showed that physics learning faces various challenges, particularly in the effectiveness of teaching methods that are still teacher-centered and dominated by lectures. Available learning modules do not fully support student needs. As a result, students view physics as difficult to understand, merely as a collection of formulas, disconnected from real contexts, and even afraid to ask questions. This results in low learning motivation and less achievement of learning objectives. In line with research conducted by Rozali et al. (2022), it states that abstract and complex physics material is often delivered through a conventional teacher-centered approach, resulting in a lack of active student involvement in the learning process.

The problems at SMAN 13 Takalar emphasize the need to develop more innovative learning modules. According to Agustin et al. (2019), teaching materials are a crucial component for both educators and students, both at school and independently. Various types of teaching materials can be used in the learning process, including modules. These materials are very diverse, including printed and non-printed (Kelana & Pratama, 2019). The use of structured learning modules can be a solution to improve the quality of learning, encourage student learning independence, increase learning interest, and make students more active (Aris et al., 2024). Prastowo (2011), emphasized that learning modules emphasize student activity more than teacher activity. These modules are usually self-contained, meaning they can be studied independently by students because they are systematic and comprehensive. Thus, modules have great potential to help achieve scientific literacy. Furthermore, the challenges of the 21st century require students to have competencies in science, technology, engineering, and mathematics. Therefore, the STEM (Science, Technology, Engineering, and Mathematics) approach is an appropriate strategy.

Learning with STEM integration is a form of learning that is compatible with the current curriculum system in Indonesia (Zulaiha & Kusuma, 2020). Science, Technology, Engineering, and Mathematics (STEM) is an approach that integrates more than one discipline. Learning using STEM can help students solve problems and draw conclusions from previous learning by applying it through science, technology, engineering, and mathematics (Puspitasari et al., 2021). Furthermore, according to Brown (Ridha et al., 2022), STEM is a school-level meta-discipline where science, technology, engineering, and mathematics are taught in an integrated manner by teachers, and each discipline's material is not separated but handled as a dynamic whole. The integration of Science, Technology, Engineering, and Mathematics (STEM) into the learning process is very possible. The integration of STEM education into the school curriculum opens up exciting possibilities for engaging students in authentic learning experiences that encourage critical thinking, promote collaborative group work, and enable creative problem-solving (Mp, 2014). Furthermore, according to Aguilera et al. (2021) and Allen et al. (2019), starting and implementing effective STEM learning in the classroom is a challenge and will have a positive impact on the learning process.

The STEM approach emphasizes innovation, while materials serve as resources that assist instructors in classroom teaching and learning activities (Sihombing et al., 2025). Teachers can use STEM to show students how ideas, rules, and laws from science, technology, engineering, and mathematics are combined into the creation of everyday systems, processes, and products (Martawijaya et al., 2023). Previous research also reinforces this urgency. The results of previous research conducted by Lika et al. (2024) obtained an n-gain score of 0.63, indicating a difference in students' understanding of physics before and after the implementation of the STEM-based physics module. In addition, positive responses were obtained to learning using the STEM-based module. The STEM-based learning model can improve understanding of physics concepts more effectively than conventional methods (Senopati & Mahardika, 2025). This supports previous research stating that the STEM approach can improve the quality of physics learning by connecting theory with practical applications (Astuti et al., 2017). Statistical analysis showed a significant difference between the experimental and control groups, confirming the effectiveness of this approach in physics learning. Furthermore, according to Zahirah et al. (2023) the implementation of STEM can also significantly improve students scientific literacy skills in the knowledge aspect.

Module development is a crucial factor in teaching and learning activities, particularly in secondary schools (Mustafa et al., 2020; Doyan et al., 2020). Developing STEM-based physics modules is crucial for improving the quality of learning and students' scientific literacy. The quality of the developed product plays a crucial role in product development in education (Tunnisa et al., 2022). The development of STEM-based physics modules requires expert assessment to determine the feasibility and validity of the developed module. According to Silvia (2024), assessment is a systematic and systematic effort carried out through the collection of valid and reliable data or information in an effort to make considerations for decision-making. According to the Big Indonesian Dictionary (KBBI), an expert is a person (specialist) or specialist. Therefore, expert assessment is an assessment carried out by experts in a particular field through the collection of valid and reliable data or information in an effort to make considerations for decision-making. Each expert is asked to assess the product that has been created to identify the weaknesses and strengths of the designed product (Sugiyono, 2020). Furthermore, a developed physics module can be considered high-quality if it meets three assessment criteria: validity, practicality, and effectiveness (Heryani, 2022). A suitable physics module is one that has been validated by experts, received feedback from teachers, and demonstrated effectiveness.

Validity comes from the word validity, which means the extent to which a measuring instrument (test) is accurate and precise in carrying out its measurement function. A test is said to have high validity if the instrument performs its measurement function accurately or produces measurement results that are in accordance with the purpose of the measurement. This means that the measurement results are quantities that accurately reflect the actual facts or conditions of what is being measured. Therefore, validity is an assessment of the accuracy of product design in accordance with actual conditions (Ramadhan et al., 2024). Validation of teaching materials is reviewed from the aspects of format, language, content, presentation of teaching materials, and the benefits of teaching materials. The validity of a learning tool is determined by comparing the validity criteria of the learning tool and the results of the assessment scores obtained (Purnama et al., 2024).

Furthermore, the quality of learning development products must meet three criteria, one of which is that the developed learning products must be practical (Annisa et al., 2020). Practicality refers to the ease of use of the developed learning materials by both students and educators, ensuring meaningful, engaging, enjoyable, and useful learning for students, while also enhancing creativity in learning (Milala et al., 2021).

Research conducted by Musaad et al. (2023) showed that developing teaching materials using the ADDIE model resulted in valid, practical, and effective modules. Furthermore, Urmila et al. (2023) developed a module using a STEM approach, which was deemed suitable for use by students.

Unlike previous research, the novelty of this study lies in the development of a STEM-based physics learning module specifically designed and implemented in the local context of students at SMAN 13 Takalar. This learning module not only integrates elements of science, technology, engineering, and mathematics in general, but is also designed based on observations and real needs in the field, including the limitations of learning modules used so far and the minimal connection of the material to contextual issues. Furthermore, this study not only assesses the validity and practicality of the module but also directly measures the effect of its use on improving students' scientific literacy.

Based on the description above, the researcher will develop a STEM (Science, Technology, Engineering, and Mathematics)-based physics learning module and its impact on students' scientific literacy skills. The purpose of this study is to analyze the validity of the STEM-based physics learning module, analyze the practicality of the module, and analyze the impact of the use of the physics learning module on students' scientific literacy skills".

Method

The type of research used in this study is research and development. The development model used in this study is the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation.

Analysis

Initial Needs Analysis

An initial needs analysis was conducted to identify the background of the problems encountered in the physics learning process, thus deeming the need for the development of a STEM-based physics module. This is evident from the analysis of textbooks used at SMAN 13 Takalar, which demonstrates that the Merdeka Curriculum requires learning resources that provide students with the flexibility to create quality learning tailored to their needs and learning environment. The textbooks used in physics learning do not accommodate this, as they still primarily present material without incorporating a STEM approach. Furthermore, the curriculum analysis identified scientific literacy as one of the core competencies to be achieved in learning. The textbooks used in schools only present basic material and concepts, lacking in practical application. Therefore, it is clear that the textbooks used do not reflect the learning outcomes set out in the Merdeka Curriculum.

Student Analysis

Student analysis aims to examine student characteristics, including their background knowledge and the language they use, and specifically their learning styles, which include visual, auditory, and kinesthetic. The distribution of learning styles among eleventh-grade students at SMAN 13 Takalar can be seen in Figure 1.

Based on the distribution of students' learning styles, data obtained shows that students have various learning styles (audio, visual and kinesthetic). Based on the results of data analysis, among the three types of learning styles (audio, visual and kinesthetic) students in grade XI tend to have a kinesthetic learning style, this can be seen in the data analysis, where 41.67% of students have a kinesthetic learning style, 27.78% audio and 30.56% Visual. This means that students tend to enjoy learning by involving physical movements, touching and feeling or experiencing something independently, so an appropriate learning model is needed so that students are active and motivated in learning.

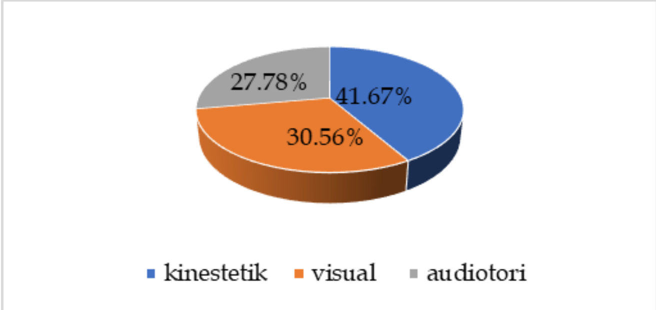

Figure 1. Learning styles of class XI students at SMAN 13 Takalar

Concept/Material Analysis

The material analysis aims to identify and systematically organize the main concepts that students will learn as reference material for researchers in developing STEM-based physics learning modules. Based on the material analysis conducted, the material to be developed is sound waves and light. This material was chosen because of its numerous applications in everyday life that can be linked to the students' environment.

Learning Objective Analysis

The analysis of learning objectives is based on the Learning Outcomes (CP) and the learning objectives outlined in the curriculum regarding the identified material concepts. The learning outcomes developed in the STEM-based physics learning module are aligned with the outcomes of other STEM-based physics learning modules, which have characteristics that align with the STEM-based physics learning module being developed.

Design

The design stage is the planning stage for the framework of the STEM-based module being developed. The design stage in module product development is based on the needs analysis stage. This stage involves selecting teaching materials appropriate to the identified problems and selecting teaching materials that will be used in the learning process and can assist teachers in the learning process so that students can master the concepts being taught. The design of this STEM-based physics learning module is structured based on learning activities that integrate aspects of science, technology, engineering, and mathematical equation calculations to solve a problem.

Development

This stage is the production stage of the STEM-based module, which is suitable for use. The STEM-based physics learning module and the scientific literacy test instrument were validated by three experts, who are postgraduate physics lecturers at Makassar State University, to determine the module's validity. Validity was determined using the Aiken's V formula, as shown in equation 1.

$$v = \frac{\sum s}{n(c-1)} \quad (1)$$

Description:
V: Rater (validator) agreement index regarding item validation
S: Score assigned by each rater (validator) minus the lowest score used (s = r-I_0) with r being the score for the rater's chosen category, I_0 being the lowest score
n: Number of raters
c: Highest validity assessment score

Implementation

The developed STEM-based physics learning products or modules will be assessed for their practicality by practitioners or physics teachers in schools. The practicality test is aimed at product users, namely subject teachers. Ten physics teachers completed a practicality questionnaire covering aspects of content suitability, presentation, language, and graphics. The results of the product practicality assessment were then analyzed using equation 2.

$$PRS = \frac{\sum A}{\sum B} x100\% \quad (2)$$

Description:
PRS : Percentage of practitioners responding to the categories stated in the instrument
∑A : Total score obtained for each category stated in the questionnaire
∑B : Maximum score for each category responding to the questionnaire

Based on the percentage values obtained, they are then categorized according to the practitioner assessment score percentage criteria in Table 1.

Table 1. Practicality Categories

Percentage (%)	Category
76-100	Very Practical
51-75	Practical
26-50	Less Practical
0-25	Not Practical

After assessing the practicality of the developed module, a trial was conducted. The trial was conducted to determine the effect of using a STEM-based physics module on students' scientific literacy skills. At this stage, the trial was conducted using an experiment with a True Experimental Posttest Only Control Design model, as shown in Table 2.

Table 2. Posttest Only Control Design (Sugiyono, 2020)

	Class	Treatment	Posttest
R	Experiment	X	O_1
R	Control	-	O_2

Description:
O_1 : Posttest in the experimental class
O_2 : Posttest in the control class
R : Randomized
X : Use of STEM-based physics modules
- : Use of textbooks

The trial subjects for the implementation of the STEM-based physics learning module were class XI of SMAN 13 Takalar, consisting of two classes: an experimental class and a control class. The experimental class was taught using the STEM-based physics learning module, while the control class was taught using the conventional module. After the learning process, both students were given a previously validated science literacy test. To determine the effect of the STEM-based physics learning module on students' science literacy skills, data from the posttest were analyzed using inferential statistics.

Evaluation

The evaluation stage is a crucial step in the module development process because it assesses the effectiveness of the designed module and its impact on students' scientific literacy skills. This evaluation involves analyzing post-test data, or a pilot test of the STEM-based physics learning module, to determine its impact on improving students' scientific literacy skills.

Result and Discussion

Results of the Development of a STEM-Based Physics Learning Module

Based on the needs analysis conducted in grade 11 of SMAN 13 Takalar, researchers developed a draft of a STEM-based physics learning module covering sound and light waves. The chosen format for development was a printed module. This selection was based on considerations regarding supporting learning activities, particularly during face-to-face classroom instruction. The use of structured learning modules can be a solution to improve the quality of learning, encourage student learning independence, increase learning interest, and make students more active (Aris et al., 2024).

The development of a STEM-based physics learning module includes: The initial section of the module consists of a cover and introduction, containing general information about the STEM-based physics learning module being developed. The cover is designed to be as attractive as possible, with fonts, illustrations/images, and colors that align with the characteristics of the module being developed. Furthermore, the introduction includes a foreword, module usage instructions, and a table of contents. The main content of the STEM-based physics learning module covers the main material, namely Sound Waves and Light. This section is systematically structured according to the STEM approach, which links physics concepts with aspects of science, technology, engineering, and mathematics. Furthermore, each section of the material is presented through learning activities that include contextual problems based on the stages of the STEM approach and indicators of scientific literacy. This aims to improve students' scientific literacy and relate physics concepts to everyday life.

Figure 2. STEM-based physics module cover

The final section of the STEM-based physics module includes a summary and practice questions with answer keys. This section aims to measure students' understanding of the material presented. A glossary and bibliography are also included. According to Razi (2024) modules with consistent layouts and components make it easier for teachers to align modules with formal learning activities. The STEM-based physics learning module can be seen in Figure 2.

The material in this module is structured based on PISA science literacy indicators, namely identifying scientific issues, explaining scientific phenomena, and interpreting scientific data/evidence. The integration of the STEM approach steps and science literacy indicators into the module's learning activities can be seen in Figure 3.

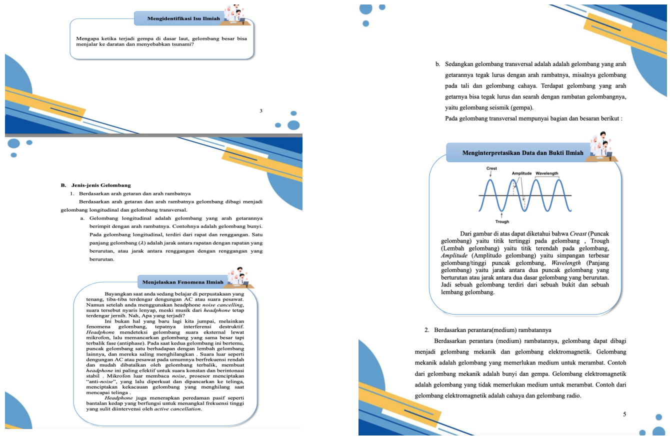
Figure 3. Integration of STEM and scientific literacy indicators in physics learning modules

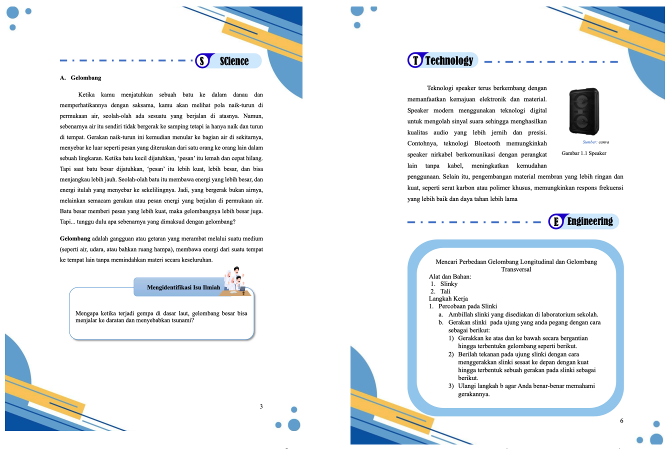

Figure 4.Integration of STEM aspects into the material

Validity of the STEM-Based Physics Learning Module

After the development process for the STEM-based physics learning module was completed, the next step was product validation. The module's validity was assessed based on its content, presentation language, and graphics. Product validation was conducted by three validators, all of whom were physics education lecturers, to assess the validity and suitability of the developed product as a teaching material. The validation results for the STEM-based physics learning module are shown in Table 3.

Table 3. Results of validity analysis of STEM-based modules

Aspect	V	Category
Content	0.77	Valid
Presentation	0.84	Valid
Language	0.78	Valid
Graphics	0.83	Valid
Mean	0.81	Valid

Validity comes from the word "validity," which refers to the extent to which a product accurately performs its intended function (Kartini et al., 2019; Saifuddin, 2019). Content validity is determined by expert consensus to assess the designed product. Each expert is asked to assess the product to identify its strengths and weaknesses (Retnawati, 2016).

The table above shows that the content feasibility aspect obtained a validity index (V) of 0.77, making it a valid category. The presentation feasibility aspect obtained a validity index (V) of 0.84, making it a valid category. Furthermore, the language feasibility aspect obtained a validity index (V) of 0.78, making it a valid category. The graphic feasibility aspect obtained a validity index (V) of 0.83, making it a valid category. The findings of this study also strengthen existing scientific findings, as shown by research Nazifah et al. (2022), Ulya et al. (2023), and Wiyono et al. (2025) which found that STEM-based teaching materials were declared valid based on expert validation results.

The developed learning module is able to increase student active involvement in the learning process and help them connect physics concepts to real-world problems, thus enabling students to gain a deeper understanding of physics concepts. This also aligns with the research findings of Alfiras et al. (2020) who found that students tend to prefer printed textbooks over e-books because they are considered more convenient for learning. Research by Syahiddah et al. (2021), found that this STEM-based physics module can provide solutions to everyday problems because the material is integrated with the four STEM fields.

Practitioner Assessment of STEM-Based Physics Learning Modules

According to Gao et al. (2020) well-designed assessments can provide quality information. In the context of developing teaching materials, such assessments play an important role in ensuring that the developed product is effective and suitable for use. Practicality refers to the extent to which the developed product can be used easily and efficiently by teachers and students in the learning process. A teaching material can be said to be practical if it meets the following criteria: expert and practical assessment that the device can be used with little or no revision, teachers and students state that the developed device is easy to use and the results of observations of the implementation of teaching materials in the classroom are included in the good or very good category (Aleslami, 2020). The STEM-based physics learning module that was declared valid by experts was then given to practitioners to assess the implementation and usefulness of the developed Physics learning module. Practitioners in this study were 10 high school/Islamic high school (SMA/MA) Physics teachers. Among them, 2 teachers came from SMAN 13 Takalar and 8 Physics teachers came from several high schools that are members of the Physics MGMP group throughout Takalar Regency.

The Physics learning module was assessed by practitioners using a validated and valid questionnaire. The practitioner response questionnaire consisted of four aspects: content suitability, presentation suitability, language suitability, and graphic suitability, consisting of 43 statements. The practicality of the developed STEM-based physics module was assessed through the practitioners' responses. The analysis of the practitioners' response questionnaire concluded that 93.8% of practitioners gave a positive response to the STEM-based Physics learning module. This assessment result was supported by practitioners' direct assessments when assessing the developed module. The analysis results from each practitioner are presented in Table 4.

Table 4. Practitioner Assessment Result of STEM-Based Physics Modules

Aspects	Percentage (%)	Category
Content	93.65	Very Practical
Presentation	93.89	Very Practical
Language	92.71	Very Practical
Graphics	95	Very Practical
Mean	93.8	Very Practical

Based on the analysis of practitioner assessments in the table above, it can be seen that practitioners rated the aspects of content, presentation, language, and graphics as very practical. The content feasibility aspect received a score of 93.65%, presentation 93.89%, language 92.71%, and graphics 95%. The overall average percentage for each aspect was 93.8%. This indicates that the physics learning module is considered very practical and suitable for use in school learning.

This research finding is supported by research Oktarina et al. (2023) on STEM-oriented e-modules that meet the requirements for being a very suitable or very practical tool for use in teaching and learning activities. Furthermore, identifying student needs prior to product development not only received a positive response from teachers but was also considered a practical approach for classroom implementation (Ariyani et al., 2025; Nursyahitna et al., 2024; Rungkat et al., 2023).

The results of this analysis are in line with research conducted by Kiswanda et al. (2023) which stated that the development of STEM-based physics E-modules with the principles of sustainable development towards the scientific literacy of grade XI students was stated to be very practical to use. Furthermore, research conducted by Ardiyanti et al. (2022) on the development of STEM-based physics teaching materials (Science, Technology, Engineering, and Mathematics) stated that the developed physics teaching materials can be stated to be very suitable for use as learning resources. In line with Sakti's research Sakti (2025), the development of STEM-PBL-Based E-Modules concluded that the developed electronic modules were valid and effective where the practicality test was through teacher and student responses. Meanwhile, research by Ridha et al. (2022) obtained that the results of the practicality test analysis of STEM-based learning devices included practical criteria and received positive responses from teachers and students.

Results of the Analysis of the Influence of STEM-Based Physics Learning Modules on Scientific Literacy Skills

After validity and practicality tests were conducted, the developed physics learning module was piloted. This aimed to determine whether the STEM-based physics learning module had any effect on students' scientific literacy skills. Therefore, to see its effect, a trial was conducted using a True Experiment with a posttest Only Control Design model. The trial was conducted using two classes, namely the experimental class and the control class. Both classes were not given a pretest, but a posttest after being given the treatment. The experimental class was given treatment in the form of the developed STEM-based physics learning module, while the control class used conventional teaching materials generally used in the school. Furthermore, after the learning process took place, both classes were given a science literacy test.

After administering the science literacy test, student score data were obtained from the experimental and control classes. The science literacy score data were then processed to determine the effect of the use of STEM-based physics learning modules on students' science literacy. Parametric statistical analysis was performed using the t-test (independent sample t-test). Before testing the hypothesis, the data must first undergo prerequisite tests, namely normality and homogeneity tests. The normality test for the data in this study used the Liliefors test. The results of the normality test analysis of the science literacy scores of the experimental and control classes can be seen in Table 5.

For the experimental class, the L-value was 0.09, while the L-critical value at the 5% significance level was 0.15. Because the calculated L-value < the critical L-value, the experimental class data were normally distributed. Meanwhile, for the control class, the calculated L-value was 0.10 and the critical L-value was 0.16. Therefore, it can be concluded that both data were normally distributed and met the requirements for further parametric testing.

Table 5. Results of Data Normality Test Analysis

Data	Calculated L-value	Critical L-value	Result
X	0.09	0.15	Normal
O	0.10	0.16	Normal

After the normality test was conducted, the next step was to conduct a homogeneity test. The homogeneity test was conducted to determine whether the variances between the experimental and control classes were homogeneous. The homogeneity test was conducted using the F-test. The results of the homogeneity test for the scientific literacy skills of students in the experimental and control classes are shown in Table 6.

Table 6. Results of Data Homogeneity Test Analysis

	X	O
Mean	23.97	20.94
Variance	6.482	7.729
Observations	32	31
df	31	30
$f_{calculated}$		1.191
$f_{critical}$		1.835

Based on Table 6, the variance of the experimental class is 6,482 and the control class is 7,729, resulting in an F count of 1,191. The F count value is then compared with the F table value with a significance level of 5% with degrees of freedom df1 = 31 and df2 = 30, which is 1,835. Because F count < F critical, it can be concluded that both groups have homogeneous variances. Thus, the homogeneity assumption required to conduct a parametric test (t-test) is met. The results of the t-test (independent sample t-test) can be seen in Table 7.

Table 7. Results of Independent Sample t-Test Analysis

	X	O
Mean	23.97	20.94
Variance	6.482	7.729
Observations	32	31
df		61
$t_{calculated}$		4.54
$t_{critical}$		1.99

Based on Table 7, the average score of the experimental class's scientific literacy test was 23.97 with a variance of 6.482, while the control class obtained an average score of 20.94 with a variance of 7.729. The calculated t-value was 4.54. Meanwhile, the t-table value at a significance level of 5% with degrees of freedom (df = 61) was 1.99. Since the calculated t-value > critical t-value, it can be concluded that there is a significant difference between the results of the experimental and control classes' scientific literacy test. The STEM-based physics learning module has a significant effect on improving students' scientific literacy skills. These findings are in line with research Hutomo et al. (2022) that students can solve problems in questions well with the help of e-modules packaged in STEM. Students can connect the material they have learned in the module with problems in real life. According to Dasgupta et al. (2019) STEM can engage students more actively in learning and make it easier for students to observe technology and its applications and natural phenomena that exist in everyday life. In line with research Ilma et al. (2024), Nafahah et al. (2025), Nisya et al. (2024) that this teaching material is proven to improve students' scientific literacy skills and is effective for implementation in learning and receives positive responses and is suitable for application in physics learning.

Research conducted by Dewi et al. (2023) showed an increase in students' scientific literacy outcomes after being provided with module-based teaching materials during the learning process. This finding aligns with research by Kamal et al. (2024) and Nurwati et al. (2025) which both confirmed that the use of STEM-based teaching materials in experimental classes can significantly improve students' scientific literacy. Similarly, Fortus et al. (2022) emphasized that the primary goal of scientific literacy is not only to improve conceptual understanding but also to maximize interest in learning STEM, as well as foster students' confidence and motivation in their ability to continue learning STEM.

Conclusion

The STEM-based physics learning module developed in this study has been validated for use as a teaching material in the classroom learning process. This conclusion is based on the results of the validity analysis conducted by three expert validators which produced a validity score of 0.81 which is in the valid category. Meanwhile, the practicality analysis of the STEM-based physics learning module showed a score of 93.8%, which is in the very practical category. After the validity and practicality tests, a limited trial was conducted to examine the effect of the STEM-based physics learning module on students' scientific literacy skills. The results of the limited trial showed that the use of the STEM-based physics learning module had a significant effect on students' scientific literacy skills compared to learning that did not use the module. This finding was supported by the results of the statistical analysis using the t-test, which revealed that the average posttest score of the experimental class was significantly higher than that of the control class, with a t-count value of 4.54 which exceeded the t-table value of 1.99 at a significance level of 5%. Therefore, the developed module is considered appropriate for use as an alternative contextual teaching material in order to support the progress of students' scientific literacy skills, especially in physics subjects.

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Author Contributions
Conceptualizing research ideas, research methodology, data analysis, thesis development process, original drafts writing, software requirements for instructional module design, management responsibilities, and coordination in planning and conducting research activities: M. Writing, reviewing, and editing; supervising and validating the instructional module and research instruments: MSA, HA.

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Conflicts of Interest
The author declares that there is no conflict of interest in this research.

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