



## Development of a STEM-Based Learning Module on Heat and Temperature to Improve Students' Scientific Literacy

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### ABSTRACT

Scientific literacy is the ability of students to understand, explain scientific phenomena, and use scientific knowledge in decision making, however the scientific literacy of students in Indonesia is still relatively low. This development research aims to analyze the validity, practicality, and effectiveness of learning modules with a STEM approach to temperature and heat material to improve scientific literacy of grade VII junior high school students. This study uses the 4D development model (Define, Design, Develop, and Disseminate). The module product was tested on 10 students in a small group trial and 28 students in a large class trial at SMP Negeri 27 Banjarmasin. The data were analyzed descriptively with validity analysis techniques using the Aiken's V formula, practicality analysis based on the percentage of student response questionnaires, and effectiveness analysis using the N-Gain value from the pretest and posttest results. The results showed that the learning module obtained a validity score of 0.92 (very valid), practicality of 90.54% (very practical), and *N-Gain* of 0.84 (high category). Based on these results, the STEM-based learning module is feasible to use, practical and effective in improving students' scientific literacy.

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## INTRODUCTION

Twenty-first century science education demands that students develop skills that extend beyond just knowledge; they must also be proficient focus on thinking, problem solving, communication, and teamwork. Scientific literacy, which includes the capability to comprehend and articulate scientific concepts as well as utilize scientific information in making informed choices, serves as a key measure of how prepared students are to tackle global issues. However, various research results indicate that the level of scientific literacy among Indonesian students is still thought to be poor. Based on data from the Programme for International Student Assessment (PISA) conducted from 2000 to 2022, Indonesia consistently recorded poor scores in science literacy, with an average of only about 56.86% (Ilannur *et al.*, 2020; Sujudi *et al.*, 2020). Even

after the COVID-19 pandemic, science literacy scores have not shown significant improvement (Marwah & Pertiwi, 2024).

Physics learning is one of the science subjects, so its learning activities must include processes, scientific attitudes, and products (Erlinawati *et al.*, 2019). In the context of physics learning, the material of temperature and heat is one of the topics encountered. Temperature and Heat are essential topics in physics that learners must comprehend as their ideas are intimately connected to daily experiences (Ma'rifah *et al.*, 2016). Additionally, this is emphasized by the creation of educational modules using a STEM approach to assist students in understanding these ideas more effectively. The lack of scientific understanding results from several reasons, including teacher-focused instruction, dull and unengaging teaching resources, along with limited connections between science ideas and everyday experiences (Yusmar and Fadilah, 2023). In science education, students tend to be directed towards memorizing facts and theories rather than mastering concepts and real applications. This situation is exacerbated by the limited engaging learning media and the lack of experimental facilities in schools.

Science, Technology, Engineering, and Mathematics (STEM) has been proven to be a successful method for improving scientific knowledge. This approach integrates the four fields into an applicable and contextual learning experience, helping students understand the interrelationship between concepts and apply them in real problem-solving (Permanasari, 2021; Sakti *et al.*, 2022). STEM also encourages students to be active in project-based learning, experiments, and activities that emphasize higher-order thinking. Indonesian education advocates for the use of the STEM method to cultivate learners who are creative, analytical, and adaptable in the current climate (Annur *et al.*, 2022).

Several research results indicate the success of developing STEM-based teaching materials in improving learning outcomes and science literacy. In 2023, Kiswanda, Putri and other researchers conducted research, while in 2024 they found evidence that STEM module content is valid, applicable (for educational purposes), and results good in education; Sari and his team report this result not only reinforces but also strengthens skills related to scientific communication and problem-solving. In the context of temperature and heat, one of the important topics in junior high school science, the use of relevant and contextual learning modules is necessary because this topic is closely related to everyday phenomena and requires a strong conceptual understanding.

Modules are one of the effective learning resources as they are systematically designed to support both self-directed learning and learning with the guidance of educators (Utami, Jatmiko, & Suherman, 2018). Learning modules are designed to maximize the achievement of success indicators (Maulida, 2022). According to the Ministry of National Education, the purposes of developing teaching materials are: 1) to provide teaching materials that meet curriculum demands while considering the needs of students, 2) to help students obtain alternative teaching materials besides textbooks, and 3) to facilitate educators in conducting the teaching process (Twiningsih, 2017). Students who use the modules will receive feedback by knowing their level of learning outcomes. In junior high school science education, the material tends to involve learning activities related to the surrounding environment. The STEM approach is a viable method for imparting knowledge in science education.

Based on the discussions conducted at SMP Negeri 27 Banjarmasin affirmed that, it was found that the majority of seventh-grade students are experiencing difficulties in understanding the

material of temperature and heat. The data from the learning outcomes show that 28 out of 35 students in class VII F scored below the minimum competency standard of 75. This low understanding affects the students' ability to explain scientific phenomena and apply the concepts of temperature and heat in real life. As a result, an educational plan needs to be put in place which includes introducing rather than sponsoring 'a STEM-based module that will enhance our learners' literacy concerning science.

In order to address this issue, this research seeks to develop an educational module that utilizes a STEM approach on temperature and heat material that is valid, Effective and practical methods for incorporating science into the curriculum of seventh graders. This research adapts the 4D development model (*Define, Design, Develop, and Disseminate*), although its implementation is limited to the development stage due to time and resource constraints. In line with this background, the formulation of the problems in this research are: (1) How valid is the learning module with a STEM approach on the sub-material of temperature and heat in improving students' science literacy skills? (2) How practical is the learning module with a STEM approach based on student responses? and (3) How effective is the learning module with a STEM approach in improving students' science literacy skills based on pretest and posttest results?

The purpose of this research is to: (1) Determine the validity level of the learning module with a STEM approach on the subtopic of temperature and heat in improving students' scientific literacy skills; (2) Assess the practicality of the module based on student responses; and (3) Evaluate the effectiveness of the STEM-based learning module in enhancing students' scientific literacy skills based on pretest and posttest results. With the development of this module, it is hoped that a learning product will be created that not only helps students better understand the concepts of temperature and heat, but also equips them with scientific literacy skills relevant to the needs of the 21st century.

The purpose of research and development is to evaluate changes that occur over a period of time, to produce new products through a development process based on field test findings, which are then developed and revised (Syamsuddin & Fuady, 2020). According to Riduwan (2009), Research and Development (R&D) is the term used to describe a set of steps or phases that are intended to create essentially nailed down products, or to improve an already existing product. product so that it can be accounted for. The main goal of development research is not to formulate or test theories, but to develop products that are effectively used in schools (Ramadhan, Tressyalina, & Zuve, 2009). This aligns with Sugiyono (2013), who states that development research is a research method used to produce specific products and test the effectiveness of those products.

## **METHOD**

### **Participants**

This study was conducted over four months, starting from January 20 to April 28, 2025. The research location is situated at SMP Negeri 27 Banjarmasin, found on Jalan SMP 27, RT/RW 02/01 No. 50, Sungai Andai Village, North Banjarmasin Sub-district, Banjarmasin City, South Kalimantan. Its aim is to develop a product in the form of a learning module with a STEM approach

on the topics of temperature and heat to enhance students' science literacy skills. The specific objective is to assess the validity, practicality, and effectiveness of the developed learning module. The subjects of this research are seventh-grade students of SMP Negeri 27 Banjarmasin for the academic year 2024/2025. The small group trial involved 10 seventh-grade students from class VII G, while the field trial (large class) involved 28 students from class VIIF.

### **Procedures**

The kind of investigation conducted in this paper is known as development research or Research and Development (R and D). The model applied for development is the 4D framework (*Define, Design, Develop, and Disseminate*), which was created by Sivasailam Thiagarajan in 1974. Nevertheless, in this study, it only carried out up to the third stage, which is Develop, due to limitations in time and cost. The reason for selecting the 4D model is that it systematically designed specifically for developing learning devices and has been widely used in similar research.

### **FINDINGS AND DISCUSSION**

The approach utilized in this study is the 4D framework introduced by Sivasailam Thiagarajan. The reasons why the 4D model selected for this study consists of the following elements: (a) the 4D model is structured in an organized order of tasks; (b) the 4D model is uniquely designed for creating educational models rather than for designing lessons; (c) the 4D model has been extensively applied in studies focusing on the creation of educational models. The 4D framework was created by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel. This model includes four phases, which are to define, design, develop, and disseminate (Latief, 2009; Wahyudi, 2021).

This research follows the steps of the 4D development approach (Define, Design, Develop, and Disseminate), which has been tailored to fit the research focus for undergraduate students. The first stage is the Define stage, initiated by a needs analysis through interviews with science teachers at State Junior High School 27 Banjarmasin. This interview seeks to recognize issues in the education experience, particularly related to the low understanding of students concerning the material of temperature and heat, as well as the low proficiency in scientific literacy. Additionally, a curriculum analysis and characterization of students are also conducted to ensure the appropriateness of the material and the approach to be used in the learning module. Subsequently, The Design phase is conducted by arranging the layout of the educational module, which consists of learning goals, learning objectives, temperature and heat materials, STEM-based experimental activities, example questions, student worksheets, and learning evaluations.

The module is visually designed and its content is created using design software (Canva), to be attractive, interactive, and easy for learners to understand. The third stage, which is Develop, involves the validation of the module by five validators, made up of three specialists in Science Education and two educators in science. They are asked to provide assessments and suggestions for improvements regarding the content, language, appearance, and alignment of the STEM approach in the module. Afterward, the revised module is tested with learners in two phases,

namely a small group trial (10 learners from class VII G) and a large class trial (28 learners from class VII F). This trial aims to determine the learners' responses to the practicality of the module and to measure the effectiveness of the module in enhancing science literacy skills.

The fourth stage, Disseminate, was not conducted extensively due to time and budget limitations, thus it was only carried out in a limited manner by providing soft file modules to students and printed modules to subject teachers. The instruments used in this study consist of three types. First, a validation sheet, which is used by experts to assess the aspects of content, learning design, visual appearance, and language of the module. This validation sheet is structured in the form of a Likert scale questionnaire and analyzed using *Aiken's V* formula. Second, a student response questionnaire, which is used to measure the practicality of the learning module based on ease of use, interest, and benefits of the module. This questionnaire consists of positive and negative statements which are analyzed through percentage calculations. Third, the knowledge test instruments in the format of an initial assessment and a final assessment, which are created using the science literacy benchmarks from PISA 2022, : (1) recognizing life situations related to science and technology, (2) understanding nature and technology based on scientific knowledge, and (3) interpreting data and drawing conclusions using scientific evidence. This test consists of 10 multiple-choice questions that have been validated by experts, and is employed to evaluate the advancement of students' abilities in science literacy prior to and following the use of the module. All data obtained from these instruments are analyzed quantitatively to assess the authenticity, usability, and efficiency of the created product.

Methods for gathering data were implemented using three types of instruments, namely: validation sheets, student response questionnaires, and pre-test and post-test questions. Validation sheets are used by experts to assess the quality of the module, the questionnaires are used to determine the practicality of the module from the students' perspective, and the pre-test and post-test are used to measure the improvement in science literacy skills. Data analysis techniques were conducted quantitatively by: (1) validity analysis using *Aiken's V* formula, the formula below

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

Notes:

$V$  = Index of agreement among validators,  $s$  = Score assigned by validator minus the lowest score in the category used ( $s = r - l_0$ ),  $n$  = Number of validators,  $r$  = Highest score selected by validator,  $l_0$  = Lowest score in the scoring category ( $l_0 = 1$ ), and  $c$  = Number of scoring categories available to validators ( $c = 5$ ). (2) practicality analysis based on the percentage of questionnaire scores from student responses, The practicality value of the product is obtained based on the score calculation of the students' questionnaire responses and can be calculated using the formula by Tridiwanto & Trishandra (2020) below :

$$P = \frac{Q}{R} \times 100\% \quad (2)$$

Notes:

P = Practicality value, Q = Score obtained, and R = Maximum possible score

and (3) The effectiveness analysis of the product can be measured based on the results of the pretest and posttest science literacy knowledge test instruments. The effectiveness analysis to determine the improvement in students' science literacy skills can be identified using the normalized gain, also known as the (*N-gain*) equation. Effectiveness analysis using the *N-Gain* formula to measure the improvement in learning outcomes before and after using the module, the formula below

$$(g) = \frac{\text{Skor posttest} - \text{skor pretest}}{\text{Skor maximum} - \text{skor pretest}} \quad (3)$$

## DISCUSSION

The results of this study cover three main aspects, namely validity, practicality, and effectiveness of the STEM-based learning module on the topics of temperature and heat. Validation was conducted by five experts, consisting of three lecturers and two science teachers. The results of the analysis using *Aiken's V* formula showed that the module obtained an overall validity score of 0.92, which is categorized as very valid. The content aspect received the highest score of 0.93, indicating that the material in the module is aligned with the learning objectives and STEM principles. This reinforces the belief that the module can be used in teaching without substantial revisions. This high validity is in accordance with the research by Kiswanda *et al.* (2023), which states that STEM-based modules have good integration among components and can support meaningful learning processes. Below are the validation results of the media in table 1.

Table 1. Module Validation Results

Assessment Aspect	Validator Scores					V	Category
	I	II	III	IV	V		
Module content	18	20	17	19	20	0,93	Very Valid
Learning Design	16	20	16	20	20	0,90	Very Valid
Language	14	14	12	15	15	0,92	Very Valid
Visual /Media Display	14	15	12	15	15	0,93	Very Valid
Avarage						0,92	Very Valid

Table 1. shows the results of the validation of the learning module with a STEM approach on the material of temperature and heat, indicating that all assessed aspects received scores classified as very valid. Based on the evaluations from five validators consisting of university lecturers and science teachers, the *Aiken's V* values for each aspect are as follows: content aspect scored 0.93, learning design 0.90, language 0.92, and media display 0.93. The overall average validity is 0.92, which is categorized as very valid. These results indicate that the module meets the standards of content feasibility, integration of STEM-based learning, use of communicative language, and an attractive visual design.

The practicality of the module was tested through a response questionnaire given to 28 students after participating in learning with the module. The results indicate that the practicality percentage is 90.54%, falling into the very practical category. The students reported that the module is easy to use, visually appealing, and the experimental activities in the module help them understand the material more tangibly. These findings support the research findings of Putri *et al.* (2024), which state that the STEM approach can increase student motivation and engagement in learning. The high practicality also shows that the visual design and language of the module have been tailored to the characteristics of junior high school students.

Table 2. Practicality Result Based on Student Response Questionnaire

Number of Student	Maximum Score	Percentage	Category
28	40	90,54%	Very Practical

The results in Table 2 of the practicality test were obtained through respondent questionnaires given to 28 seventh-grade students after using the module. The practicality percentage reached 90.54%, which falls into the very practical category. Students indicated that the module was easy to use, the activity instructions were clear, and the simple experiments in the module helped them understand the material concretely. This aligns with the characteristics of junior high school students who require visual, contextual, and active learning media. The STEM approach based on direct activities also made the students more enthusiastic and independent.

Based on the table above, the results obtained from the participants' responses show an overall percentage of 90.54%, which can be categorized as very practical. Likewise, the research conducted by Puspitasari *et al.* (2021) on the development of STEM-based physics teaching materials showed very positive responses from the participants, with a percentage reaching 90.98% on the topic of temperature and heat, categorized as very positive.

The effectiveness of the module was analyzed using the results of pretests and posttests given to students before and after the use of the module. The results showed a significant increase in students' science literacy scores. The average pretest score was 46.07, while the posttest score increased to 91.07. The *N-Gain* calculation showed a value of 0.84, which is classified as high or effective. This indicates that the module successfully improved students' understanding of the material on temperature and heat. More specifically, the highest indicators of science literacy were found in questions 1 and 2, which focused on scientific knowledge (high category), while questions 3 and 4, which assessed data interpretation, showed an improvement from a low to a moderate category. These results are consistent with the study by Sari *et al.* (2025), which indicated that the use of a STEM-based module with experimental and engineering activities could enhance students' scientific thinking and interpretive skills. Posttest and Pretest data from the test are shown in Table 3.

Table 3. Average Scores of Science Literacy Test Items in Pretest and Posttest

Number of Student	Average <i>Pretest</i>	Average <i>Posttest</i>	<i>N-gain</i>	Category
28	46,07	91,07	0,84	High/Efective

In terms of effectiveness in Table 3, the data were obtained from the results of the pretest and posttest. The average pretest score was 46.07, while the posttest increased to 91.07. The *N-Gain* calculation resulted in 0.84, which falls into the high category. This improvement indicates that the use of the module can enhance students' science literacy skills, especially in the aspects of scientific knowledge and understanding of temperature and heat concepts. Science literacy indicators that were previously low in the pretest, such as interpreting scientific data, showed improvement after students engaged in experiments and problem-solving activities designed in the module.

Overall, the data obtained has supported the formulation of the research problems and objectives. The module is stated to be valid, practical, and effective for improving science literacy. The strengths of this research lie in the successful integration of STEM principles into learning that is relevant to the local context and easily applied in schools with limited facilities. The module also encourages students to actively build understanding through experimental activities, discussions, and reflections. The impact of this research is the availability of a STEM-based learning product that can be implemented to address the challenges of low science literacy in Indonesia, while also providing alternative contextual teaching materials that support the Merdeka Curriculum and 21st-century learning. The following is a description of the learning process using STEM-based learning modules in Figure 1.

Figure 1. Activities using STEM learning modules in the class



(Source: Personal Documentation, 2025)

## CONCLUSION

Based on the results of research and the development of a learning module using a STEM approach on the topic of Temperature and Heat to improve the science literacy skills of seventh-grade students at SMP Negeri 27 Banjarmasin, it is suitable for use in the learning process because the learning module has been deemed very valid with an *Aiken's V* score of 0.92, indicating that the module fulfills aspects of content, design, language, and presentation well. The learning module is very practical with a practicality score of 90.54%, which indicates that students find the module easy to use, engaging, and helpful for their learning. The learning module has proven effective, showing an *N-gain* value of 0.84 (high category), which significantly enhances students' science literacy skills. This research has several limitations that need to be considered. First, the development process was only carried out up to the development stage in the 4D model due to limitations of time, cost, and scope of research at the undergraduate level, so dissemination has not been widely conducted. Second, the product trial was only carried out at one school and with a limited sample scope, namely the seventh-grade class at SMP Negeri 27 Banjarmasin, so the generalization of the results cannot be done comprehensively. Third, the developed module is still in print form and has not maximally utilized digital technology, such as development in the form of e-modules or application-based. Recommendations Based on the results of the research, discussion, and conclusions regarding the development of the learning module using a STEM approach on temperature and heat to improve science literacy skills among students, There are several shortcomings in the research, so for future studies, it is suggested that subsequent researchers develop the learning module into an e-module version and not just in print form, possibly by utilizing supportive applications that can make it easier for students to access it anytime and prepare in terms of funding as well as allowing for more adequate research time. Educators are expected to find this learning module to be an effective and efficient tool in teaching the material of temperature and heat to students.

### **The authors declare that there is no conflict of interest in this work.**

The author declares that there is no conflict of interest in the writing and preparation of this scientific work. The entire research process, data analysis, and article writing were carried out objectively and independently, without any influence from any party that could affect the results and conclusions of the research.

## REFERENCES

- Annur, S., Rusilowati, A., Suprijadi, S., & Sumarni, W. (2022). Teaching Science, STEM Approach and Local Wisdom in Disaster Mitigation A review study from 2011-2019. In the Proceedings of the National Post graduate Seminar (PROSNAMPA) 5(1). 1075-1080.
- Erlinawati, C. E., Bektiarso, S., & Maryani. (2019). A STEM-Based Project-Based Learning Model in Physics Education. Proceedings of the National Seminar on Physics Education, 4(1), 2527–5917.

- Ilannur, A., Wulan, A. R., & Diana, S. (2020). A Study of Science Question Items on the Topic of Biology in Junior High School Regarding the Skills to Explain Phenomena Scientifically. *Journal of Educational Research*, 20 (2), 163-173.
- Kiswanda, V., Aswirna, P., & Nurhasnah. (2022). Development of STEM-Based Physics E-Module with Sustainable Development Principles on the Science Literacy of Eleventh Grade Students. *Journal of Smart Students*, 4(1), 55–63.
- Ma'rifah, E., Parno, & Mufti, N. (2016). Identification of Students' Difficulties in Temperature and Heat Material. 1, 730–742.
- Marwah, A. S., & Pertiwi, F. N. (2024). Student science literacy in innovation in product-based science learning. *Journal of Tadris Science Education Indonesia*, 4(1), 114-126.
- Maulida, U. (2022). Development of teaching modules based on the independent curriculum. *Tarbawi*, 5 (2), 130-138.
- Permanasari A. (2021) STEM Education for Nature Care (“Green Life”). Brebes
- Puspitasari, E., & Putra, P. D. A. (2021). Development of STEM-based physics teaching materials on the topic of temperature and heat in high school. *Journal of Physics Education Literacy (JLPE)*, 2(1), 44-52.
- Putri, R. Y., Surya, M. N., & Astuti, I. R. (2024). Development of a STEM-Based Science Module to Improve Problem-Solving Skills of Middle School Students on Heat and Temperature Material. *Journal of Innovative Science Education*, 10(1), 55–64.
- Ramadhan, S. Tressyalina, & Zuve, FO (2009). Textbook on Research Methods for Learning the Indonesian Language.
- Sakti, I., Nirwana, N., & Defianti, A. (2022). Implementation of STEM-Based Learning in the Course of Natural Science Studies-1 on the Subject of Temperature and Heat to Improve Students' Science Literacy. *Kumparan Physics Journal*, 5(2), 131-140.
- Sari, D. A., Rahmawati, Y., & Handayani, T. (2025). Development of Integrated STEAM and Project-Based Learning Teaching Module to Improve Communication Skills of High School Students. *Journal of Physics Education and Learning*, 13(1), 1–12.
- Sugiyono, D. (2013). Research methods in education: quantitative, qualitative approaches and R&D.
- Sujudi, M. S., Idris, T., Suryanti, S., & Handayani, P. H. (2020). Profile of Science Literacy Abilities of As-Shofa Islamic Junior High School Students in Pekanbaru Based on PISA. *Journal of Natural Science and Integration*, 3(1), 58-69.
- Syamsuddin, R., & Fuady, M. I. N. (2020). Efforts to Strengthen Research and Development Bodies and Regional Innovation in the City of Palopo. *Wawasan Yuridika Journal*, 4(1), 63-79.

- Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional development for training teachers of exceptional children: A sourcebook*. Bloomington: Indiana University.
- Twiningsih, A., Sadjidan, S., & Riyadi, R. (2017, May). Development of Thematic Learning Modules on Ecosystems Based on Problem Based Learning to Enhance Critical Thinking of Fifth Grade Students of State Elementary School Kleco 1 in Surakarta City for the 2016/2017 Academic Year. In National Seminar on Learning Technology and Basic Education 2017. 196-203.
- Utami, T. N., Jatmiko, A., & Suherman, S. (2018). Pengembangan modul matematika dengan pendekatan science, technology, engineering, and mathematics (STEM) pada materi segiempat. Desimal: *Jurnal Matematika*, 1(2), 165-172.
- Wahyudi, G., Ramadhan, S., & Arief, D. (2021). Development of thematic teaching materials based on the picture and picture model in elementary schools. *Basicedu Journal*, 5(2), 966-973.
- Yusmar, F., & Fadilah, R. E. (2023). Analysis of the low science literacy of Indonesian students: PISA results and contributing factors. *LENSA (Lentera Sains): Journal of Science Education*, 13(1), 11-19.