

Development of STEM-based Worksheets on Global Warming to Improve Students' Scientific Reasoning Ability

Yolanda Oktavia Palian, Shelly Efwinda*, and Puardmi Damayanti

Physics Education Program, Universitas Mulawarman, Samarinda, Indonesia

*shelly.efwinda@fkip.unmul.ac.id

Article Info	Abstract
Article history: Received: July 5, 2024 Revised: December 13, 2024 Accepted: January 29, 2025 Keywords: Scientific reasoning STEM Validity Worksheet This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License © 2025 Berkala ilmiah Pendidikan Fisika	Scientific reasoning is a thinking skill that students need in the 21st century to prepare them for global challenges. The research aims to develop STEM-based worksheets (Science, Technology, Engineering, and Mathematics) on global warming, which is expected to improve students' scientific reasoning skills. This research includes the Research and Development (R&D) method. This research describes the validity of the worksheet conducted by two Physics Education study program experts. The results show that the STEM-based worksheet is very valid, averaging 93.29%. Thus, the STEM-based worksheet on the topic of global warming that has been designed can be used in high school learning to improve students' scientific reasoning skills.
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INTRODUCTION

Education is an aspect that has an important role and is trusted to be able to improve the quality of students' mindsets and, in general, equip students with capital and provisions to overcome global problems and challenges ([Afni & Syamsurizal, 2022](#); [Aulia et al., 2020](#); [Novitasari et al., 2023](#)). Through education, students can stimulate their thinking to provide accurate information ([Retnowati et al., 2020](#)). The educational process in the 21st century is focused on science and technology ([Fenanda et al., 2024](#)). Scientific reasoning is one of the thinking skills needed in this century and an important goal that science education needs to teach students to prepare for global challenges ([Anjani et al., 2020](#); [Welter et al., 2024](#)). In this context, physics has a unique role because it focuses on understanding physics concepts applied in everyday life ([Damayanti, 2021](#)). Physics also plays a vital role in developing attitudes and awareness of natural science and technology development and its impacts. However, teachers often deliver subject matter without facilitating student interaction and provide less encouragement for active participation in expressing their ideas ([Widyaningtyas et al., 2024](#)). In addition, opportunities for students to analyze the topics discussed are still minimal.

As a continuation of the role of education in developing critical thinking and scientific reasoning, the importance of physics in equipping students with relevant abilities becomes very clear. One of the crucial aspects of science education is scientific reasoning, which requires special attention to ensure students can utilize it in real-life contexts. Scientific

reasoning is the ability to solve problems, which includes the process of evaluating facts, forming hypotheses, determining and controlling variables, designing and conducting experiments, collecting data, analyzing data, and drawing conclusions systematically and logically (Bao & Koeing, 2019; [Aulia et al., 2020](#); [Suaidah et al., 2023](#)). Scientific reasoning skills are needed by students to apply the knowledge gained in solving problems in everyday life ([Wulandari et al., 2024](#)). In the reasoning process, students associate the phenomenon under study with prior knowledge and then seek new knowledge, modifying and integrating previous knowledge ([Zulkipli et al., 2020](#)).

However, the studies showed that the scientific reasoning ability of Indonesian students is unsatisfactory ([Anjani et al., 2020](#)). Yet, the problem of low student scientific reasoning can be addressed by applying appropriate learning models and teaching materials ([Ristia et al., 2023](#)). Teaching materials are needed as information, tools, and texts for planning and reviewing the implementation of learning ([Rahmatina et al., 2020](#)). Through worksheet-based teaching materials, students are expected to be more productive, creative, innovative, and effective by strengthening their attitudes, skills, and knowledge in an integrated manner ([Ernawati & Sujatmika, 2021](#)).

STEM learning is one of the alternative learning models that can be used in science learning to solve global issues and problems faced today, such as global warming ([Lafifa et al., 2023](#); [Novitasari et al., 2023](#); [Sirajudin et al., 2021](#)). In this case, [Baharin et al. \(2018\)](#) state that STEM education can actively involve students in learning to motivate them to explore in-depth information about the activities. STEM is a four-pronged approach to science, technology, engineering, and math aligned with problem-based learning to enable active learning and integrate abstract concepts from each dimension ([Riyasni et al., 2023](#)). STEM learning can help students participate in cognitive processes such as generating effective solutions, solving problems, and drawing conclusions from previous learning by applying these four aspects ([Dewi, 2019](#); [Koes-H & Putri, 2021](#)).

One effort to implement the STEM approach in learning is to provide STEM-based worksheets that begin with systematic and appropriate topic design. Teachers should not just teach in the classroom; they need to practice to be able to apply what they learn to everyday life ([Baharin et al., 2018](#); [Efwindi et al., 2021](#)). Worksheets allow students to play a more active role and utilize their thinking skills ([Ristia et al., 2023](#)).

Therefore, this study aims to develop teaching material in worksheets integrated with the STEM approach to improve students' scientific reasoning skills by considering the content, language, presentation, and graphics eligibility criteria to help students improve their scientific reasoning skills.

METHODS

This research includes the Research and Development (R&D) method. R&D is the process or steps of developing a new or improving an existing product ([Okpatrioka, 2023](#)). The purpose of this study was to create STEM-based worksheets on the topic of global warming. This topic is a natural phenomenon that is currently occurring, and its impact has also begun to appear on the ecosystem on Earth, which, if left unchecked, will worsen ([Blaum et al., 2017](#); [Kumar & Pooja, 2020](#)). So, education about global warming must be considered so that students have sufficient knowledge about the phenomenon to take action and make decisions to prevent global warming. The validators for developing STEM-based worksheets are two lecturers from the Physics Education Study Program, Faculty of Teacher Training and Education, at one of the universities in Indonesia. The instrument used is an expert validation sheet with a Likert scale questionnaire consisting of five answer choices with criteria that can be seen in Table 1.

Table 1 Likert scale

Criteria	Score
Very good	5
Good	4
Enough	3
Not good	2
Very poor	1

After that, the score obtained is calculated with Equation 1:

$$\text{Results} = \frac{\text{score obtained}}{\text{maximum score}} \times 100\% \quad \dots (1)$$

The results obtained were adjusted then with the validity criteria in Table 2:

Table 2 Validity criteria

Interval	Criteria
$80 < X \leq 100$	Very valid
$60 < X \leq 80$	Valid
$40 < X \leq 60$	Moderately valid
$20 < X \leq 40$	Invalid
< 20	Very invalid

RESULTS AND DISCUSSION

As a result of this research, STEM-based worksheets have been created and validated by two lecturers, including a content expert and a media expert. The worksheet was validated by giving the validation sheet to two expert lecturers. The STEM-based worksheet contains a problem orientation that directs students to problems that occur in the present on the topic of global warming. Then, the worksheet also includes a problem letter focusing on students' scientific reasoning when solving problems. Students are then asked to design an environmentally friendly alternative energy source project to convert solar energy into electrical energy. At the end of the worksheet, some questions facilitate the development of scientific reasoning skills.

The STEM aspect integrated into the worksheet is in the science aspect; students need to apply their understanding of global warming to explore solutions to reduce the causes of increasing global warming. In the technology aspect, students learn about technology related to the issue of global warming, such as the use of technology that can reduce the causes of global warming. In the Engineering aspect, students design an environmentally friendly alternative energy source that can reduce the impact of global warming. Then, from a mathematical perspective, the amount of expenditure used and the resilience of the environmentally friendly alternative energy source project that has been designed will be calculated.

The STEM-based worksheets designed are then tested for validity by the two validators. The content expert validators include content and presentation feasibility assessment components, while the media expert validators include the language and graphical feasibility assessment components. The validation results are then calculated using the formula for the final validity value. The percentage results of each assessment component after validation can be seen in Figure 1. The validation results are obtained based on Figure 1, namely the content feasibility component (88.89%), presentation feasibility (90.91%), language feasibility (96.67%), and feasibility of graphics (96.67%).

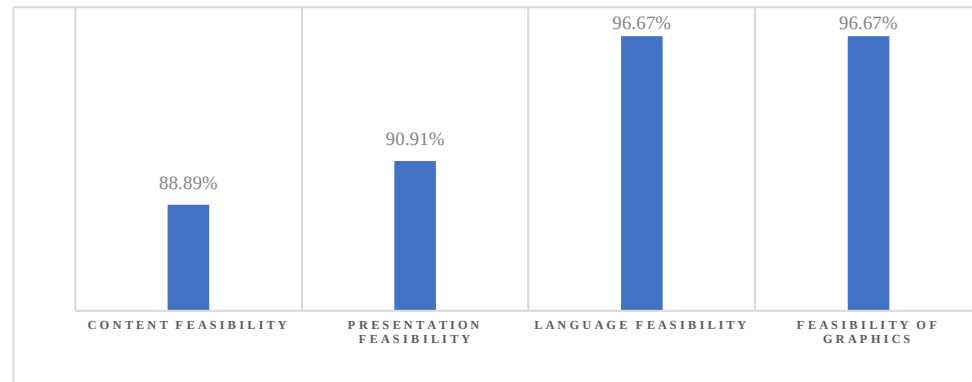


Figure 1 The percentage results of each assessment component after validation

Table 3 is the validity criteria.

Table 3 Validity criteria

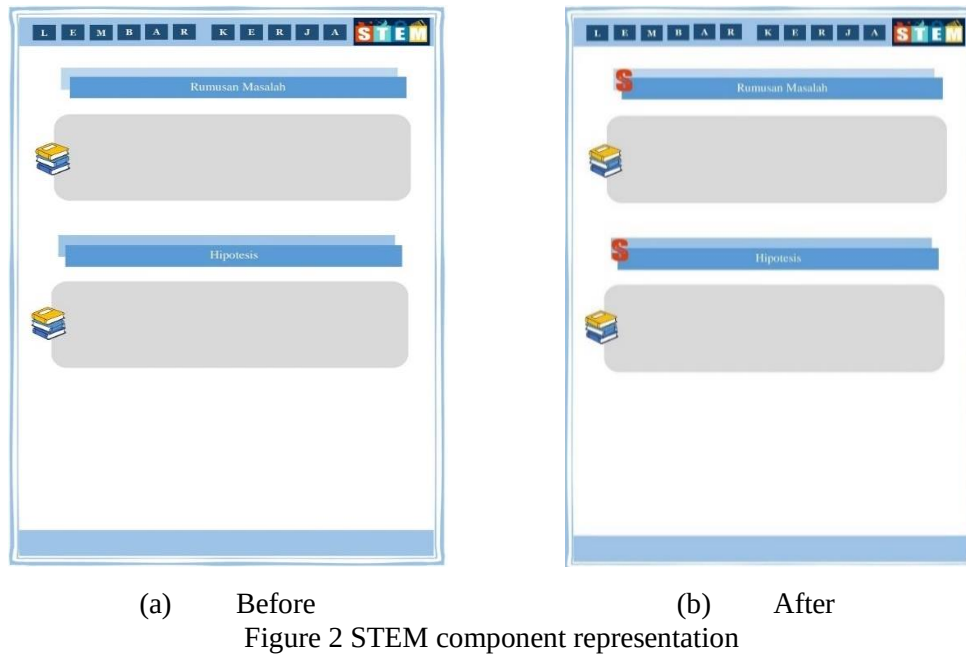
Aspect	Percentage of validity	Criteria
Content feasibility	88.89%	Very Valid
Presentation feasibility	90.91%	Very Valid
Language feasibility	96.67%	Very Valid
Feasibility of graphics	96.67%	Very Valid
Average	93.29%	Very Valid

Table 3 shows that the validity value of the STEM-based worksheet on the Global Warming topic obtained an average percentage value of 93.29% with Very Valid criteria. Two validators provided overall comments or suggestions on the STEM-based worksheet, which were then used as material for revision. The following are some of the comments and suggestions the two validators gave in Table 4.

Table 4 Validators' comments and suggestions

Expert Validators	Comments/Suggestions
Content Expert	Contents and problems are more specific and detailed. Writing each sentence in the question is made more accessible and easier to understand.
Media Expert	Clarify the representation of STEM components in the worksheet steps. Added introduction to energy-related technologies such as solar panels and their working mechanisms

The STEM-based worksheets can be improved based on the comments and suggestions from the experts. Improvements made based on comments and suggestions from validators are shown in Figures 2 and 3. Figure 2 shows the improvements made, namely clarifying the representation of STEM components in the steps in the worksheet design.



The next improvement made to the worksheet is adding an introduction to solar panel technology and how it works on the worksheet, which can be seen in Figure 3.



Figure 3 Introduction to solar panel technology

Based on the literature, the use of worksheets helps students succeed in learning by assisting them in thinking about, memorizing, and understanding content ([Rahmayani et al., 2021](#)). Teachers must design worksheets that support students throughout the learning process and enable them to achieve 21st-century skills ([Mardita et al., 2022](#)). The STEM approach is one of the solutions in 21st-century learning because it can increase students' potential ([Vanesha et al., 2020](#)). In the research results from [Hasanah \(2020\)](#), the researcher mentioned that the role of STEM has a practical impact in optimizing student assessment at the secondary school level. STEM learning can engage students in the design process and show students the concepts, principles, and science, technology, engineering, and mathematics used in an integrated way to develop products, processes, and systems that benefit human life ([Davidi et al., 2021](#); [Jovita et al., 2022](#)). In the study (Hakim et al., 2023), it was stated that using teaching materials with a STEM approach can improve students' critical thinking skills and provide opportunities for students to learn more actively and critically during project activities. This statement is in line with the research done by [Lestari et al. \(2018\)](#), which states that the use of STEM integrated with worksheets can positively impact students' reasoning skills. Using student worksheets in the classroom enables teachers to deliver topics more effectively and provides students with new experiences in the learning process. This approach encourages learning effectiveness, enhances the learning process, and facilitates students' conclusions ([Muskita et al., 2020](#); [Tarigan et al., 2019](#)). The structured nature of worksheets allows for a more organized learning environment, where students can engage with the content in a manner that promotes active participation and deeper understanding.

STEM-based worksheets, in particular, offer several advantages that contribute to students' academic success. These worksheets stimulate critical thinking, enhance memory retention, and deepen students' understanding of the topic ([Rahmayani et al., 2021](#)). Integrating the principles of Science, Technology, Engineering, and Mathematics (STEM) into the learning process, these worksheets help students develop essential skills crucial for success in the modern world.

Furthermore, developing STEM-based worksheets is instrumental in helping students explore scientific reasoning skills. These skills involve various cognitive processes, including evaluating evidence, formulating hypotheses, designing and conducting experiments, and analyzing data systematically and logically. The emphasis on STEM in education encourages students to engage with the topic in a way that mirrors the processes used by scientists and engineers in the real world ([Honey et al., 2014](#); [Bybee, 2013](#)). As a result, students are better prepared to apply their knowledge in practical settings, bridging the gap between theoretical learning and real-world application.

The limitation of this study is that the worksheets developed have not been tested in schools, and the effectiveness of their implementation in developing students' scientific reasoning has not been measured.

CONCLUSION

Based on the results of the validation test, it can be concluded that the STEM-based worksheet on the topic of global warming that has been developed is included in the very valid category. The value of each assessment component indicates this, namely: content feasibility (88.89%), presentation feasibility (90.91%), language feasibility (96.67%), and feasibility of graphics (96.67%) so that an overall value of 93.29% is obtained where this figure shows very valid criteria.

Therefore, it can be concluded that the STEM worksheet on global warming, designed to improve students' scientific reasoning skills, can be used in the learning process in high school. Yet, its effectiveness for student learning remains to be determined. Thus, future studies can be carried out to evaluate the effectiveness of the learning materials for student learning.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, YO and SE; methodology, YO, SE, PD; formal analysis, YO, SE, and PD; writing—preparation of the original draft, YO; Supervised the research process, provided critical expertise in data interpretation, ensured adherence to ethical guidelines, and Led the manuscript writing and managed correspondence with the journal and reviewers: SE; Performed additional data validation and contributed to data visualization and statistical analysis, Reviewed and edited the manuscript, providing significant input to enhance clarity and precision: PD; All authors have reviewed and approved the final version of the manuscript.

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AUTHOR PROFILES



Yolanda Oktavia Palian
yolandaoktavia04@gmail.com
Mulawarman University



Shelly Efwinda
Science Education
shelly.efwinda@fkip.unmul.ac.id
Mulawarman University
<https://scholar.google.co.id/citations?user=FpzpMcMAAAAJ&hl=id>
<https://sinta.kemdikbud.go.id/authors/profile/6034979>
<https://orcid.org/0000-0003-0715-2632>
<https://www.scopus.com/authid/detail.uri?authorId=57220036011>



Puardmi Damayanti
Physics Education
puardmi.damayanti@fkip.unmul.ac.id
Mulawarman University
Google Scholar: [SxLFqQ0AAAAJ](#)
SINTA: [6833627](#)
ORCID: [0000-0001-9941-3486](#)
Scopus Author: [58085725600](#)