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Development of Teaching Materials Based on *Predict-Observe-Explain* (POE) Model by Integrating PhET Virtual Laboratory on Temperature and Heat Material

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Abstract. Physics subjects, particularly the material on Temperature and heat, are often considered difficult due to the abstract nature of the concepts, which can lead to student misconceptions. This challenge is compounded by findings that the learning models and methods used in the field were still conventional and that many schools experience limitations in laboratory equipment for hands-on practicum. To address this gap and promote active student involvement, this study aims to develop teaching materials based on the Predict-Observe-Explain (POE) model integrated with the PhET virtual simulation on temperature and heat material. The research utilized the Research and Development (R&D) method using the 4D model (Define, Design, Develop, and Disseminate), with the study limited to the Develop stage. The research instruments included expert validation sheets and a student response questionnaire. The validation results from material and media experts obtained a high score of 89%, which is classified into the "Very Valid" category. Furthermore, the limited trials showed a positive average student response of 77%, classified in the "Good" category. The successful integration of the POE model with the PhET simulation proved effective in helping students understand the concepts of temperature and heat and increasing their active involvement in the learning process. In conclusion, the developed teaching material is highly suitable for use in the learning process at the high school level and serves as a significant practical contribution by providing an alternative interactive learning media that supports the Merdeka Curriculum.

Keywords: teaching materials, POE, PhET, temperature, heat

INTRODUCTION

The availability of teaching materials that are in accordance with student needs and curriculum developments is one of the crucial and important aspects in the educational process. Along with the development of science and technology, the education system in Indonesia is required to continue to innovate in order to improve the quality of learning (Utami, 2019). However, in reality there are still many teachers who have difficulty preparing teaching materials that can foster active student involvement in the learning process, especially in science subjects such as physics (Kamila et al., 2023; Madani et al., 2023). This is in accordance with the facts in the field obtained by researchers when conducting observations at one of the high schools in Samarinda, researchers found that the learning model and teaching methods used were still conventional styles. This situation necessitates the development of effective and engaging resources.

Physics subjects are often considered difficult because many of the concepts are abstract and not easily observed directly by students. One of the materials that often causes misconceptions is temperature and heat (Hsiao et al., 2017). This material requires a learning approach that is not only theoretical, but also encourages students to be actively involved in observing and explaining phenomena. To answer this challenge, the *Predict-Observe-Explain* (POE) learning model introduced by White and Gunstone in 1992 is considered suitable because it is able to encourage students to think critically, convey predictions, and compare observations with their understanding (Rosdila et al., 2021; Akhfari et al., 2022). Restami (2021) also mentioned that the POE Learning model is able to explore students' prior knowledge, improve their concept understanding, and ultimately contribute to improving learning outcomes. Learning using the POE method is also effective in improving concept knowledge in building students' cognitive development.

In addition to the learning model, another supporting factor that is important to consider to support the learning process, especially in physics lessons, is the availability of experimental facilities. As in the physics lesson of temperature and heat which requires practicum activities to strengthen students' understanding of abstract concepts that are difficult to understand only through theoretical explanations. With an adequate laboratory, students can conduct experiments that allow them to directly see physical phenomena related to temperature and heat. This not only improves their understanding of concepts but also their science process skills. However, currently there are still many schools experiencing limitations in laboratory equipment to conduct hands-on practicum (Anggraeni, 2021) as well as the results in the field found by researchers. Therefore, the use of technology in the form of virtual laboratories is a potential alternative that can be used to overcome the limitations of real laboratory equipment. One platform that can be utilized is the PhET (Physics Education Technology) simulation from the University of Colorado which allows students to conduct experiments interactively, flexibly, and cost-effectively (Wieman et al., 2010; Tuhusula et al., 2020).

Various previous studies have shown that the use of POE-based teaching materials integrated with PhET simulations can improve students' concept understanding and learning outcomes. Gintita et al. (2018) found that POE-based teaching materials can improve learning outcomes in cognitive, affective, and psychomotor aspects. In addition, Siti et al. (2020) showed that students who learned with the help of PhET simulation had a better understanding of the concept compared to students who did not use the simulation. This shows that the combination of POE and PhET models is very effective in learning physics, especially in temperature and heat material. However, despite the individual effectiveness of both POE and PhET models, there remains a gap in the systematic development and validation of teaching materials that optimally integrate the POE syntax with PhET simulations specifically for the challenging Temperature and Heat material, particularly as a practical solution for classrooms facing facility limitations.

Based on the description above, this study aims to develop teaching materials based on the *Predict-Observe-Explain* (POE) model integrated with PhET simulation on temperature and heat material. This study also aims to determine the validity level of teaching materials and student responses after using these teaching materials. Hopefully, the results of this development can contribute to improving the quality of physics learning at the high school level. The POE model integrated with PhET simulation is expected to complement the learning module that helps students to remain active during the learning process. Through the stages or syntax of POE, students are encouraged to learn independently, both in the classroom and outside the classroom, anytime and anywhere.

METHOD

The development of teaching materials based on the Predict-Observe-Explain (POE) model integrated with the PhET simulation utilized the modified R&D method from Borg and Galal using the 4D development model (Define, Design, Develop, and Disseminate) proposed by Thiagarajan. This model was chosen because systematic and iterative stages are highly suitable for developing educational products that require rigorous validation of instructional design and media components, which is necessary for integrating the structured syntax of the POE model with technological tools like PhET. The research was limited to the Develop stage. The procedural steps undertaken in this study are described as follows:

1. Define Stage (Analysis of Needs and Requirements)
   The define stage aimed to analyze needs, including curriculum analysis conducted through document review of the applicable syllabus for temperature and heat to identify learning objectives, analysis of student characteristics, and analysis of temperature and heat materials. Focused on identifying abstract concepts and potential misconceptions.
2. Design Stage (Initial Product Preparation)
   The design stage includes designing initial products in the form of interactive teaching materials that contain POE syntax and PhET simulations. The material was compiled and formatted using the Canva platform to ensure flexibility and accessibility via various devices. The instruments for the Develop stages, expert validation sheets and student response questionnaires were also prepared at this stage based on BSNP (National Education Standards Agency) criteria.
3. Develop Stage (Expert & Students)
   The initial product was subjected to evaluation by two independent expert validators, one material expert and one media expert. Expert selection was based on their competence and experience in physics education and educational media development. The teaching material underwent limited trials with 15 students (based on standard R&D small-scale testing) selected from one class at the research location. Expert scores were collected and converted into a percentage score, which was then interpreted using the predetermined categories of validity (very valid, valid,etc.) to ensure the material was theoretically and practically sound. Student feedback was gathered using a student response questionnaire. The average percentage of student responses was calculated and interpreted into categories of practically (e.g., Good,Very Good).
4. Disseminate Stage (Clarifying Limitation)
   The disseminate stage was not fully implemented in this study. The research was strictly limited to the develop stage, focusing only on the validity and practicality assessment through limited trials. The limitations is acknowledged in the conclusion section and implies that the generalizability of the product is primarily based on expert judgment and small-scale feedback

RESULT AND DISCUSSION

Data collection techniques were carried out through survey methods, using instruments in the form of expert validation questionnaires and student response questionnaires.The research instruments were adapted and modified based on the BSNP (National Education Standards Agency) guidelines to ensure content and construct alignment with the criteria for assessing effective teaching materials. The instrument development focused on four main aspects: content, presentation, linguistics, and graphics. For expert validation, presented in Table 1. And three aspects: interest, material, and language. For student response, presented in Table 2. The validity of the instruments themselves was established through expert judgment, a formal reliability test (e.g., Cronbach's Alpha) was not conducted, a limitation acknowledged in this study.

Table 1. Expert Validation Questionnaire Instrument According to BSNP

Criteria	Indicator
Content Validation Aspects	a. Material suitability
	b. Accuracy of the material
	c. Recency of material
	d. Encourage curiosity
Presentation Validation Aspect	a. Presentation technique
	b. Presentation support
	c. Presentation of learning
	d. Coherence and coherence of thought
Aspects of linguistic validation	a. Straightforward
	b. Communicative, Dialogical and interactive
	c. Conformity with good and correct Indonesian language rules
Graphic Validation Aspect	a. Size of teaching materials
	b. Design of teaching materials
	c. Content design of teaching materials

Table 2. Student Response Questionnaire Instrument in accordance with BSNP

Student Response	Indicator
Student Response	a. Interest in teaching materials b. Materials in teaching materials c. Languange in teaching materials

The questionnaire results were then categorized based on the predetermined scoring guidelines. The scores obtained from each validator and student are converted into a percentage, then interpreted into categories of very valid/worthy, valid/worthy, quite valid/worthy, or invalid for validation questionnaires; and categories of very good, good, quite good, or less good for student response questionnaires. Determination of these categories refers to the score interpretation criteria according to the applicable feasibility standards as detailed in Table 3.

Table 3. Categories of Validity Level

Score Percetage %	Category
$80 \leq P \leq 100$	Strongly Agree/Eligible
$60 \leq P < 80$	Agree/Fit
$40 \leq P < 60$	Moderately Agreed/Advanced
$20 \leq P < 40$	Disagree/Inappropriate
$0 \leq P < 20$	Strongly Disagree/Eligible

This research has produced interactive teaching materials designed using the Canva platform and are shown in Figure 1. The design process using Canva is classified as very simple because it can be accessed easily through mobile devices. This makes the media practical, flexible, and can be used anytime and anywhere.

Figure 1. Teaching Material Design

All aspects of the assessments, including the feasibility of content, presentation, language, and graphics, obtained validation values between 86% and 100%, all of which are classified in the "Very Valid" category and can be seen in Table 4. This confirms that the teaching materials developed have met the criteria for excellent quality from various assessment aspects.

Table 4. Expert Validation Results

No.	Assesment Aspect	Score	Validation Value (%)	Category
1.	Content Feasibility	48	87	Very Valid
2.	Presentation Feasibility	43	86	Very Valid
3.	Linguistics	30	100	Very Valid
4.	Graphics	58	89	Very Valid

The detailed validation results in Table 4 reveal insightful variations among the assessed aspects. The highest validation value was achieved in the linguistic aspect (100%), indicating that the language used is highly straightforward, communicative, and adheres perfectly to proper Indonesian grammar rules. This outcome is crucial as clear language supports the structured steps of the POE model. Conversely, the presentation feasibility aspect received the lowest score (86%). Although still classified as very valid, this relatively lower score suggests that while the instructional flow is sound, minor refinements in the structuring or layout of the teaching materials are still recommended to enhance the aesthetic and navigational experience for users.

The results of small_scale development trials by analysing student responses to the teaching materials are presented in Table 5.

Table 5. Student Response Questionnaire Results

No.	Assesment Aspect	Percentage (%)	Category
1.	Interest	77	Good
2.	Material	78	Good
3.	Language	78	Good

Based on Table 5, the overall average of student responses is 77%, which is classified in the "Good" category. Student interest, material clarity, and language all received highly positive feedback (77% to 78%). This demonstrated that students gave a positive response to the use of the POE-PhET teaching materials for learning temperature and heat material.

The high validation result (very valid) and positive student response (good) explicitly confirm that the developed POE-PhET teaching materials are not only theoretically valid but also practically acceptable to students, successfully fulfilling the initial aims of this study is the development of teaching materials and the determination of their validity and practically.

These findings advance previous works that focused on the effectiveness of POE models (Lebdiana & Hindarto, 2015; Putri et al. 2022; Sari & Alarifin, 2016) by providing a validated R&D product that systematically integrates the POE model with the technological support of PhET simulation. This integration is the study's novelty, specifically addressing the dual challenge of abstract concepts of temperature and heat materials and limited physical laboratory facilities, a gap identified in the introduction. While previous studies proved the effectiveness of POE in remediation or improving cognitive ability, the current study goes further by providing a ready to use, highly validated instructional product designed for practical application in a resource limited context, thus offering a concrete alternative for supporting the Merdeka Curriculum.

Although the results are promising, it is important to acknowledge the scope limitations of this R&D research. This study was confined to the develop stage, focusing on expert validation and small-scale student trials. The research did not include large-scale classroom implementation, longitudinal effectiveness testing, or comparison with a control group. Therefore, the findings primarily attest to the product's validity and initial practicality, but not its generalized effectiveness over time or across broader populations. These aspects are suggested for future research

CONCLUSION

Based on the research and development conducted, it can be concluded that the developed teaching materials successfully meet the established feasibility criteria. Expert validation results, which cover the aspects of content, presentation, language, and graphics, obtained an average score of 89% and are classified in the “very valid” category. Furthermore, student responses to the POE-integrated PhET teaching materials showed an average percentage of 77% classified in the “good” category. Both of these results explicitly confirm that the developed teaching materials are not only theoretically valid but also practically acceptable to students, thereby successfully fulfilling the initial aims of this study, which were to develop the teaching materials and determine their validity level and student responses. The integration of the POE model with the PhET simulation proved effective in increasing student active involvement and supporting a deeper understanding of temperature and heat concepts. Therefore, these teaching materials can serve as an alternative interactive learning media that supports the implementation of the Merdeka Curriculum, especially in schools facing laboratory facility limitations.However, it must be acknowledge that this research was limited to the develop stage, which did not include large-scale classroom implementation or the measurement of long-term effectiveness. As a suggestion for future research, it is recommended to the test the application of these teaching materials to other physics topics or at different educational levels to examine broader applicability, and to conduct effectiveness testing using experimental methods to measure the learning impact comprehensively.

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