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Development of Problem-Based Physics Teaching Modules on Climate Change and Weather for High Schools

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Abstract: *Climate change and weather are now problems that affect the whole world and are bad for the environment and for people's lives. Sadly, a lot of high school students still don't understand the basics of climate change because the material is too abstract and hard to understand. For example, they think that daily weather is a form of long-term climate change. To solve this, a Problem-Based Learning (PBL) physics module was made for high school students to teach them the basics of climate change and weather. The module was created to follow the Merdeka Curriculum's Deep Learning principles of being mindful, meaningful, and fun. This study employed an R&D methodology utilizing the ADDIE model. Three experts (in material, curriculum, and pedagogy) were involved in the validation process. 23 students were used in individual and small group trials to test practicality. The average validity score was 86.78% and the average practicality score was 82.82%. Both of these scores are in the Very Valid and Very Practical ranges. These results show that the module is a good choice for use as a contextual teaching tool that helps with understanding concepts, engaging the mind, and being aware of the environment.*

Keywords: *ADDIE, climate change , deep learning, merdeka curriculum, problem-based learning, teaching module*

Pengembangan Modul Ajar Fisika Berbasis Problem-Based Learning Materi Perubahan Iklim dan Cuaca untuk Sekolah Menengah Atas

Abstrak: Perubahan iklim dan cuaca sekarang menjadi masalah yang memengaruhi seluruh dunia dan berdampak buruk bagi lingkungan dan kehidupan manusia. Sayangnya, banyak siswa SMA yang masih belum memahami dasar-dasar perubahan iklim karena materinya terlalu abstrak dan sulit dipahami. Misalnya, mereka berpikir bahwa cuaca harian adalah bentuk perubahan iklim jangka panjang. Untuk mengatasi hal ini, modul fisika Pembelajaran Berbasis Masalah (PBL) dibuat untuk siswa SMA untuk mengajarkan mereka dasar-dasar perubahan iklim dan cuaca. Modul ini dibuat mengikuti prinsip-prinsip Pembelajaran Mendalam (*deep learning*) Kurikulum merdeka yaitu *mindful, meaningful, dan joyful*. Penelitian ini menggunakan metodologi *R&D* yang memanfaatkan model *ADDIE*. Tiga orang ahli (dalam materi, kurikulum, dan pedagogi) dilibatkan dalam proses validasi. Sebanyak 23 siswa digunakan dalam uji coba *one-on-one trial* dan *small group triall* untuk menguji kepraktisan. Skor validitas rata-rata adalah 86,78% dan skor kepraktisan rata-rata adalah 82,82%. Kedua skor ini berada dalam kategori Sangat Valid dan Sangat Praktis. Hasil-hasil ini menunjukkan bahwa modul tersebut layak untuk digunakan sebagai alat pengajaran kontekstual yang membantu pemahaman konsep, melibatkan pikiran, dan kesadaran terhadap lingkungan.

Kata kunci: ADDIE, *deep learning*, kurikulum merdeka, modul ajar, perubahan iklim, *problem-based learning*

INTRODUCTION

Climate and weather change are global issues that impact ecosystems, food security, and the social and economic aspects of communities (Amelia et al., 2024). To help students learn more about the environment, they need to know the basics of climate change, like how the greenhouse effect works, the difference between weather and climate, and how human activity speeds up global warming (Sartika et al., 2023). Some studies, however, indicate that pupils still lack a comprehensive understanding of this topic. This is likely due to the abstract nature of the information, which is easy to misinterpret (Fajrin et al., 2024). We need a way to teach that not only gives students information but also makes them want to think about what they're learning and get involved with it. The current Merdeka Curriculum claims that this is the main premise underpinning deep learning.

The Merdeka Curriculum (Nabila et al., 2025) calls deep learning "mindful, meaningful, and joyful." This means that how well you understand something is more important than how much you know. The Ministry of Education and Culture highlighted this method in 2025. It helps kids learn more about topics, think critically, solve real-world issues, and use what they've learned in new situations. To use these ideas, teaching modules need to be relevant, diverse, and encourage high-level cognitive involvement. All of these characteristics naturally align with the Problem-Based Learning (PBL) framework.

PBL is a good way to help students develop higher-order thinking skills. It does this by having students look at real-world problems and analyze, evaluate, and synthesize information about them (Gita et al., 2022; Utari et al., 2023). PBL facilitates the integration of scientific concepts with contemporary environmental challenges, including the increase in global average temperature, severe weather events, and rising sea levels, within the intricate, multifaceted, and practically significant domain of climate change and meteorology (Ramandani et al., 2023). Asma Sidik et al., (2025) and Putri et al., (2023) show that PBL can help students think more critically and learn more about science when it comes to global warming. This makes it a great way to use Deep Learning in science classes.

Numerous development studies have investigated the formulation of PBL-based teaching modules over the past decade. Anggraeni et al., (2022) found that 86.66% of media experts and 89.33% of subject matter experts rated PBL-based e-modules on global warming as very valid. This means that they can be used as learning tools. Likewise, Nilyani & Ratnawulan, (2023) created a PBL-based physics e-module incorporating 21st-century abilities, achieving an Aiken's V validity score of 0.97%, signifying exceptional academic viability. Fitri et al., (2024) discovered that the incorporation of ethnoscience into PBL-based e-modules not only enhances validity but also fortifies students' environmental literacy. Recent advancements indicate that scientific educators have commenced the integration of artificial intelligence (AI) to formulate contextual teaching modules aligned with the tenets of Deep Learning (Setiawati et al., 2025).

However, the majority of these research focus on global warming in general. PBL teaching modules have not been developed for the subtopics of climate change and weather fundamentals, which are the primary concepts that aid in our understanding of climate challenges. Misconceptions about these subtopics are common, such as confusing normal weather with long-term climate change, therefore an educational approach that encourages discussion, data analysis, and the interpretation of natural phenomena is required (Afkarina et al., 2024). Teaching modules must follow the principles of differentiation, contextuality, and meaningfulness in addition to being scientifically correct within the framework of the Merdeka Curriculum (Nabila et al., 2025; Setiawati et al., 2025). The teaching modules in this research consist of straightforward printed and digital learning texts that comply with

the standards for Merdeka Curriculum teaching modules, as opposed to the prevalent development of interactive multimedia-based e-modules in contemporary literature. This study aims to assess the validity and applicability of teaching modules based on Problem-Based Learning regarding the fundamentals of climate and weather change, employing expert evaluation and student feedback.

METHOD

This study employs a Research and Development (R&D) methodology, referencing the ADDIE framework (Analysis, Design, Development, Implementation, Evaluation) formulated by Dick and Carey (Rahayu, 2025). The study was conducted at Yadika Baturaja High School during the second semester of the 2025/2026 academic year. The study participants included professional validators, encompassing experts in the subject matter, curriculum, and pedagogy, along with 10th grade students from Yadika Baturaja High School who participated in the practicality assessment.

In the field of climate and weather change, the research stages are: (1) analysis, which finds needs, student traits, and basic skills; (2) design, which includes setting learning goals, organizing content, adding the PBL model, and making tools for validation; and (3) development, which means making PBL-based teaching modules and having them checked by experts. (4) putting the program into action, which meant trying it out with small groups of twenty students and one-on-one with three students to see if it worked; and (5) evaluation, which meant making changes based on what was learned during the implementation.

This study did not perform field trials or summative evaluations, as its primary focus was on the creation of a viable and useful product, rather than on empirical validation of its efficacy. Following the ADDIE R&D paradigm during the first development phase, the study concentrated solely on validity and practicality as essential criteria for feasibility prior to doing effectiveness testing in subsequent research. The tools utilized to gather data were expert validation sheets and practicality sheets for students. Both employed a Likert scale with five response categories, which may be shown in Table 1.

Table 1. Validity and Practicality Calculation Scale

Answer Categories	Score
Strongly agree	5
Agree	4
Neutral	3
Disagree	2
Disagree	1

Use the following equation to find the expert validation percentage, formula (1).

$$\mathrm{VA} = \frac{\text{Total score for each indicator}}{\text{Overall maximum score}} \times 100\% \quad (1)$$

The percentage indicates the validity level of the produced training module, with the findings according to the criteria outlined in Table 2.

Table 2. Validity Criteria

Percentage (%)	Category
84.2 – 100	Very Valid
68.2 – 84.1	Valid
52.0 – 68.1	Valid Enough
20.0 – 51.9	Invalid

To find out how useful the indicator is, use the following formula (2)

$$Practical = \frac{Total\ score\ obtained}{Maximum\ score} \times 100\% \quad (2)$$

Put the percentage findings into groups based on the rules in Table 3.

Table 3. Practicality Criteria

Percentage (%)	Category
81 – 100	Very Practical
61 – 80	Practical
41 – 60	Quite Practical
21 – 40	Less Practical
< 20	Not Practical

RESULTS AND DISCUSSION

Analysis

We used Google Forms to send an online questionnaire to 30 students to collect data for the student needs analysis. The analytical results were shown in graphs to make them easier to understand and talk about.

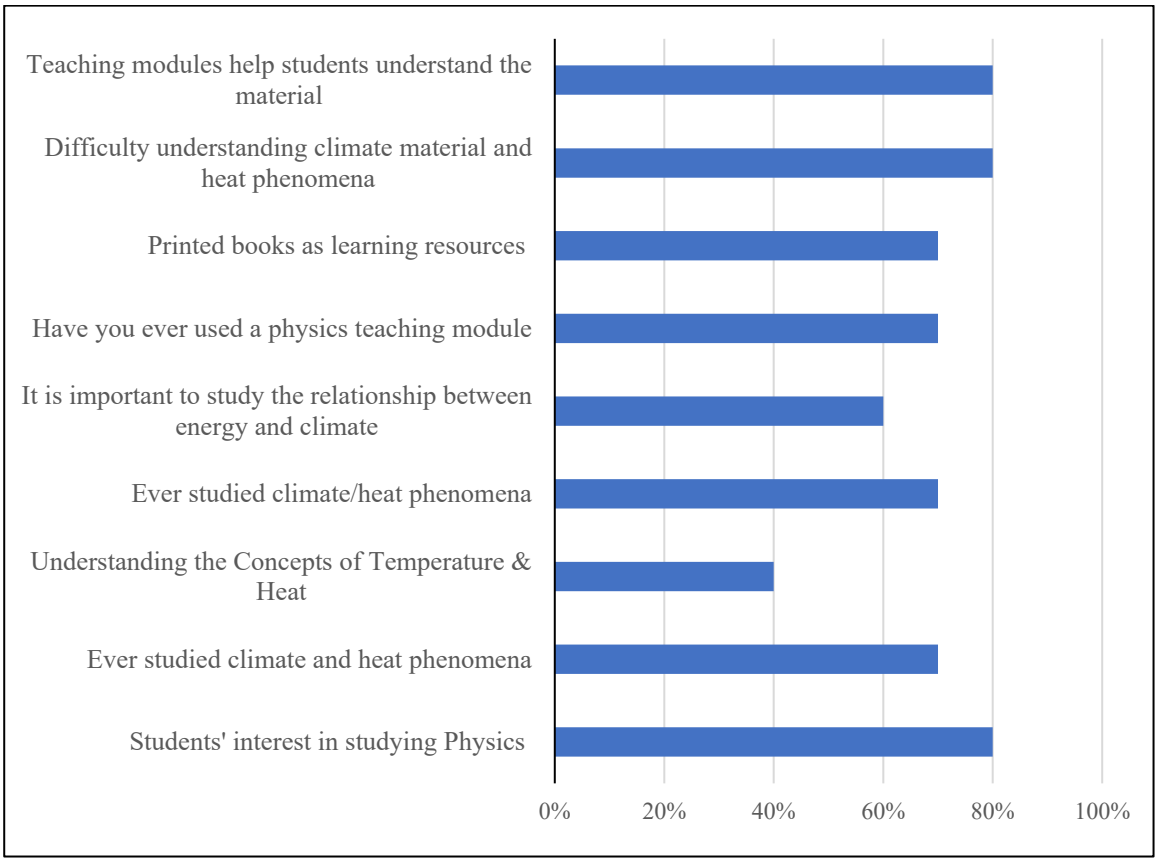

Figure 1. Results of Student Needs Analysis

Based on answers students, most of them (80%) said they wanted to learn physics, and 80% had also studied things linked to climate or heat phenomena. But just 40% of pupils said they grasped the basics of heat and temperature, and 60% said they had trouble grasping climate and heat phenomenon content in school. 70% of the people who answered said they have studied climate and weather change, and 70% of those people said it was necessary to investigate the link between energy and climate. Seventy percent of students

claimed their schools still utilized printed books as teaching resources, but sixty percent said they had used teaching modules to learn physics. Eighty percent of students said that teaching modules could help them understand the material better, which shows that there is a real need for teaching modules that are more contextual, interactive, and specifically designed for the topic of the basics of climate and weather change.

Design

In this study's design phase, a rough draft of the teaching module was created. The goal was to come up with an idea for the product based on the ideas of PBL and the Merdeka Curriculum framework. At this point, the module was broken down into three primary parts. The title, author name, fundamental information, phase/class, subject, time allocation, a method to determine if the pupils are ready, and the characteristics of the materials are all included in the first section. The most crucial portion is the core component. It includes learning activities an introduction, core activities like video presentations, heat absorption experiments, discussions, and presentations, and a conclusion with a Kahoot quiz and reflection, learning design learning outcomes, learning objectives, dimensions of the Pancasila Student Profile, contextual topics, sparking questions, and meaningful understanding, and integrated assessments initial, process, and final assessments. The module's last section includes Student Worksheets (LKPD), topic-related reading materials, a glossary, and a list of references. This design is meant to make deep learning more attentive, meaningful, and fun, while also making sure that physics principles are connected to real-world problems.

Deploment

At this point, the finished teaching module product is put together based on the design that was made earlier. Then, specialists check it and make changes depending on their feedback. Expert validation seeks to evaluate the appropriateness of the generated product for application in the learning process (Anggraeni et al., 2022). The following are the results of the feasibility evaluation by specialists in the subject matter, the curriculum, and the way of teaching.

Table 4. Expert Validation Results

Aspect	Indicator	Score	Maximum Score	Percentage Score
Material	Appropriateness and Accuracy of Materials	34	40	85%
Curriculum	Curriculum Alignment	29	35	82,85%
Teachers	Feasibility of Learning Strategies	37	40	92,5%
Average VA Results Category				86,78% Very Valid

The Problem-Based Learning-based teaching module on the basics of climate and weather change got an average score of 86.78% from experts in the subject, curriculum, and pedagogy. This is considered Highly Valid. This accomplishment demonstrates that the teaching module has satisfied the academic feasibility criteria in three primary areas, requiring only minor adjustments, specifically substituting Bullets Library with tiny abc Number Formats as outlined.

Table 5. Improvement Results based on Validator Suggestions

Before Revision	After Revision
• **IPS:** menelaah peran manusia dan aktivitas sosial ekonomi dalam perubahan iklim. • **Bahasa Indonesia:** Menulis laporan hasil eksperimen/praktikum dan menyampaikan hasil diskusi berupa tulisan maupun lisan. **III. TUJUAN PEMBELAJARAN** • Setelah menyaksikan video tentang konsep cuaca dan iklim yang ditayangkan oleh guru, peserta didik dapat menjelaskan perbedaan cuaca dan iklim serta memberikan contohnya. • Setelah berdiskusi dengan guru menggunakan LKPD pada materi Dasar-dasar Iklim dan Fenomena Panas, peserta didik mampu mengidentifikasi faktor-faktor yang memengaruhi iklim dan mengaitkannya dengan fenomena panas di lingkungan sekitar. • Setelah melakukan eksperimen sederhana yang terdapat didalam LKPD pada materi Dasar-dasar Iklim dan Fenomena Panas, peserta didik mampu menjelaskan konsep penyerapan dan pemancaran radiasi termal oleh permukaan bumi. Serta mampu mengomunikasikan hasil eksperimen dan diskusi secara lisan maupun tertulis dengan menggunakan istilah ilmiah yang tepat. **IV. TOPIK PEMBELAJARAN KONTEKSTUAL** • Perbedaan suhu antara pagi dan siang hari • Perbedaan antara cuaca dan iklim • Perubahan pola musim yang tidak menentu • Dampak peningkatan suhu terhadap lingkungan lokal • Permukaan bumi menyerap dan memancarkan energi panas • Perubahan suhu lingkungan dan iklim mikro di sekitar mereka • Isu global pemanasan bumi dan perubahan iklim **V. PERTANYAAN PEMANTIK** Tahukah kamu, Mengapa saat siang hari terasa lebih panas dibandingkan pagi hari ? Mengapa bisa berbeda?	c. **IPS:** menelaah peran manusia dan aktivitas sosial ekonomi dalam perubahan iklim. d. **Bahasa Indonesia:** Menulis laporan hasil eksperimen/praktikum dan menyampaikan hasil diskusi berupa tulisan maupun lisan. **III. TUJUAN PEMBELAJARAN** a. Setelah menyaksikan video tentang konsep cuaca dan iklim yang ditayangkan oleh guru, peserta didik dapat menjelaskan perbedaan cuaca dan iklim serta memberikan contohnya. b. Setelah berdiskusi dengan guru menggunakan LKPD pada materi Dasar-dasar Iklim dan Fenomena Panas, peserta didik mampu mengidentifikasi faktor-faktor yang memengaruhi iklim dan mengaitkannya dengan fenomena panas di lingkungan sekitar. c. Setelah melakukan eksperimen sederhana yang terdapat didalam LKPD pada materi Dasar-dasar Iklim dan Fenomena Panas, peserta didik mampu menjelaskan konsep penyerapan dan pemancaran radiasi termal oleh permukaan bumi. Serta mampu mengomunikasikan hasil eksperimen dan diskusi secara lisan maupun tertulis dengan menggunakan istilah ilmiah yang tepat. **IV. TOPIK PEMBELAJARAN KONTEKSTUAL** a. Perbedaan suhu antara pagi dan siang hari b. Perbedaan antara cuaca dan iklim c. Perubahan pola musim yang tidak menentu d. Dampak peningkatan suhu terhadap lingkungan lokal e. Permukaan bumi menyerap dan memancarkan energi panas f. Perubahan suhu lingkungan dan iklim mikro di sekitar mereka g. Isu global pemanasan bumi dan perubahan iklim **V. PERTANYAAN PEMANTIK** Tahukah kamu, Mengapa saat siang hari terasa lebih panas dibandingkan pagi hari ? Mengapa bisa berbeda?

Implementation

The professionals that checked the training module said it was quite legitimate and ready to be used. The next step was the implementation stage, which was meant to test how useful the teaching module was by having high school students utilize it in small groups. The trials were done in two parts: first, a one-on-one trial with three students, and then a small group experiment with twenty students. The following results were gathered from a student response questionnaire that asked about ease of use, content appropriateness and clarity of information, motivation and module design, values and attitudes towards the environment, engagement and learning activities as Figure 2.

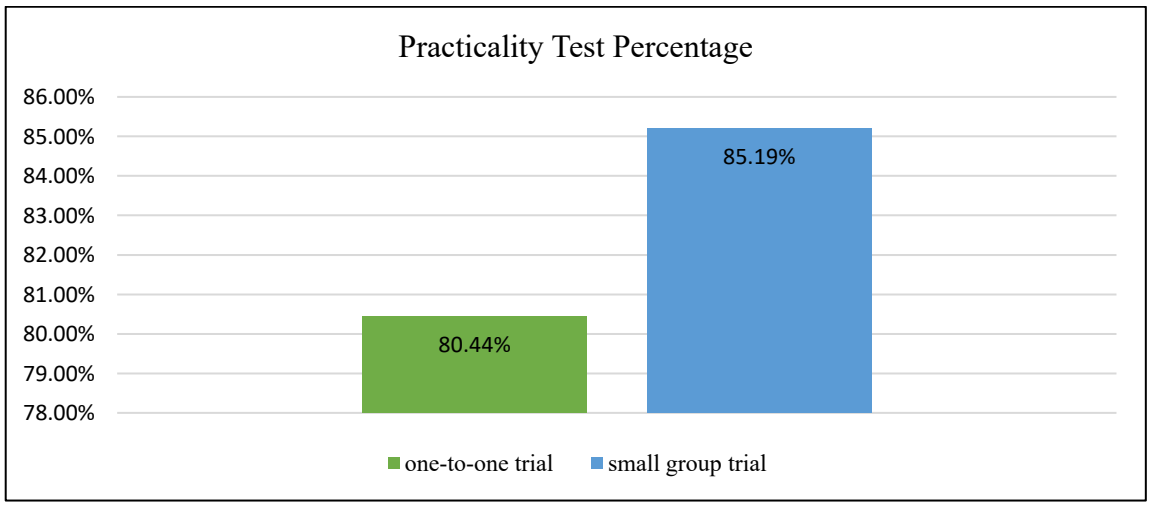

Figure 2. Practicality Test Results

The study showed that the module got an average score of 85.19% in the small group trial and 80.44% in the one-on-one trial. Both of these scores were considered Very Practical. The average score from both testing stages was 82.82%, which was very useful.

Evaluation

The evaluation phase of this study concentrated on formative evaluation, an assessment methodology executed during and subsequent to development to enhance product quality prior to broader utilization. The Development and Implementation stages talked about two primary parts of this evaluation: (1) getting experts to agree with it and (2) testing it out with real users (students).

According to the validation results from experts in the subject matter, curriculum, and pedagogy, the teaching module got an average score of 86.78%, which is considered Highly Valid. This means that the scientific content, how it fits into the Merdeka Curriculum, and the PBL methods all meet standards for teaching and learning. Based on what validators said, a few small changes were made to make the instructions clearer and the layout more consistent. For example, the numbering format in the reflection evaluation section was changed.

Next, we did a limited number of trials with students to see how practical it was. These comprised one-on-one trials with three students and small group trials with twenty students. The response questionnaire results showed that the training module got an average score of 85.19% in the small group trial and 80.44% in the one-on-one trial. The overall average was 82.82%, which, according to the criteria of this study, puts it in the Very Practical category. These results show that the teaching module is straightforward to grasp, useful in everyday life, makes people think, and can help people learn in a way that is both useful and fun.

The field trial (large-scale trial) and summative evaluation (measurement of impact on learning outcomes) stages were not conducted; however, the formative evaluation performed was adequate to determine that the teaching module is valid and effective as instructional material for high school physics education on the topic of climate and weather change fundamentals. According to the ADDIE approach and research and development criteria, this assessment stage is the first step in ensuring the module is of high quality before it can be deployed in a real-world learning setting (Fitri et al., 2024; Nilyani & Ratnawulan, 2023). Because it is contextual, interactive, and adheres to deep learning principles which emphasize mindful, meaningful, and joyful learning the PBL-based teaching module developed for the sub-subject of the fundamentals of climate change and weather is superior to traditional teaching materials (Nabila, et al., 2025). This tackles the educational challenges in the Merdeka Curriculum, where students must be able to link their knowledge with actual environmental concerns like climatic anomalies and global warming in addition to being able to recollect ideas (Ashari, 2025).

This training module also includes tasks based on real-life problems, like figuring out why cities and villages have different temperatures and how well black and white surfaces absorb heat. These activities directly foster critical thinking and collaboration among students (Ramandani et al., 2024). Prior research indicates that the PBL methodology enhances students' understanding of environmental issues and fosters critical thinking regarding global warming (Asma Sidik et al., 2025; Fitri et al., 2024).

Experts in subject matter, curriculum, and pedagogy have agreed that making teaching modules based on PBL is a good idea. The average rate of validation was 86.78%. Students rated them highly when asked about their usefulness, with an average score of 82.82% in the Very Valid category. These findings corroborate the studies conducted by

Anggraeni et al., 2022 and Nilyani & Ratnawulan, 2023, demonstrating that PBL-based modules and e-modules on climate change are highly valid and beneficial. This means they are good for helping high school physics students learn what they need to know for the 21st century.

CONCLUSION AND SUGGESTIONS

We have successfully built a high school physics teaching module on the basics of climate and weather change using the ADDIE method and Problem-Based Learning. Experts in the topic, the curriculum, and the way of teaching have all said that this module module highly valid 86.78%. It contains accurate scientific information, follows the Merdeka Curriculum, and helps with Deep Learning. The average result on the module's practical examinations was 82.82%, which placed it in the Very Practical category. This suggests that it is easy to use, important, and can encourage kids to think. The goal of this curriculum is to help students understand climate challenges better by using a contextual approach and important scientific activities. Teachers are encouraged to utilize a same methodology in creating problem-based instructional resources for further scientific subjects.

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