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Development of a Differentiated Project-Based e-Worksheet Using the STEM Approach to Foster 21st-Century Skills of Students on the Topic of Global Warming

Siti Aisyah*, Agus Suyatna, and Viyanti
Physics Education, Universitas Lampung, Lampung, Indonesia
*sitiaisyah041217@gmail.com

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Abtract

Learning about global warming in schools is often theoretical and lacks meaningful, real-world problem-solving activities that engage students. As a result, students' 21st-century skills, such as critical thinking, collaboration, and digital literacy, are not optimally developed due to the lack of innovative, differentiated learning media, including project-based e-worksheets that utilize the STEM approach. This study aims to develop a differentiated, project-based student worksheet utilizing a STEM approach that is valid, practical, and effective in training students' 21st-century skills, particularly in the context of global warming and the greenhouse effect. The research method used is development research, with the ADDIE design, consisting of the stages Analyze, Design, Development, Implementation, and Evaluation. This research was conducted in three meetings at SMAN 1 Katibung. Data analysis techniques include percentage analysis for validity and practicality scores, as well as statistical analysis to determine effectiveness. The results show that the differentiated worksheet developed has high validity in terms of content, construct, language, and design, with a score of 87.08%. In terms of practicality, it demonstrates high levels of readability, attractiveness, and feasibility, scoring 88.3%, categorized as very practical. Furthermore, the e-Worksheet has been proven effective in fostering students' 21st-century skills, as evidenced by N-Gain scores of 0.61 (moderate improvement) for critical thinking and 0.56 (moderate) for creative thinking. The application of differentiated learning in the experimental class showed a moderate effect size of 0.469 for critical thinking skills and 0.294 for creative thinking skills. These findings indicate that the differentiated project-based e-worksheet can accommodate students' varying needs, including their initial abilities and learning styles, and is necessary to support the development of 21st-century skills.

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INTRODUCTION

One of the main demands of 21st-century education in Indonesia is preparing students with essential 21st-century skills, including creative thinking, critical thinking, communication, and collaboration, to enrich and deepen their learning experiences (Bocakova, 2022; Wulandari, 2023). These competencies are crucial for students to thrive and succeed in a rapidly changing world. Twenty-first-century skills are a set of abilities, knowledge, and attitudes that enable individuals to effectively navigate and succeed in today's complex, technology-driven, and rapidly changing world. These skills include critical thinking, creativity, communication, collaboration, digital literacy, and adaptability, preparing learners for global challenges and opportunities (Bocakova, 2022).

Students must be equipped to tackle real-world issues such as global warming, which has been a pressing challenge since the mid-20th century. Society must take adaptive and mitigation measures to counter the negative impacts of global warming (Jurs et al, 2021; Mousaddar, 2025; Prayogi, 2020). Experts agree that human activities have significantly contributed to climate change since the 1950s. Rising global temperatures can hinder crop growth, potentially leading to severe food crises. If left unaddressed, this poses a serious threat to humanity's future (EPA, 2018). Thus, students must understand global warming and its mitigation strategies, and have access to related scientific literature. Global warming is an ideal topic in physics education to foster science literacy (Hasan, 2024; Keniah, 2023; Yeni et al., 2024).

Interviews with physics teachers at SMA Negeri 1 Katibung revealed that educators face challenges in teaching global warming effectively, highlighting the need for efficient learning media. Additionally, to prepare students for future life challenges, education must go beyond content delivery; it should actively train students in the four essential 21st-century competencies: critical thinking, creativity, communication, and collaboration (Martin, 2022). Developing these skills requires deliberate, structured guidance, supported by collaborative learning environments that foster students' ability to think creatively and critically, while enhancing teamwork and communication (Harasim, 2017). Research findings highlight current shortcomings in the education system. Studies have reported low levels of critical and creative thinking (Akmam et al., 2020), poor oral and written communication skills (Dunbar et al., 2006), and weak team collaboration (Suganda et al., 2021). Needs analysis surveys confirm that current teaching practices fail to nurture critical and creative thinking effectively. Many students can solve basic quantitative problems but struggle with complex problem-solving due to teaching strategies that emphasize mathematical calculations over higher-order thinking (Bayuningsih, 2018; Latifa, 2019). Therefore, 21st-century skills should be explicitly taught in high schools to prepare the next generation to handle real-world problems creatively. There is a clear gap between the ideal vision for student skills and current classroom practices. This study focuses on how to effectively stimulate critical thinking, creativity, communication, and collaboration through physics instruction, especially on topics such as global warming and the greenhouse effect. To achieve this, it is necessary to develop a differentiated project-based electronic worksheet that fosters these 21st-century skills.

Differentiated instruction is a method designed to accommodate students' diverse learning needs. Teachers serve as facilitators who tailor learning experiences to students' individual characteristics, such as learning styles, through diagnostic analysis (Risnawati, 2023). Differentiated learning has been shown to improve mathematical reasoning (Ditasona, 2017), increase student engagement and comfort (Aprima & Sari, 2022), and enhance academic achievement. It can be applied across subjects and adapted to fit various teaching models rooted in constructivist theory, including Problem-Based Learning (PBL), PjBL, and blended learning (Manalu et al., 2023; Triyanto, 2016; Yustina, 2022). The chosen model should align with the subject matter and students' capabilities.

As technology evolves, the job market is shifting toward roles that require new skills. Critical thinking, problem-solving, creativity, and collaboration are becoming increasingly essential. Creativity drives innovation and competitiveness, while problem-solving helps individuals adapt to change. Students equipped with these competencies are better prepared to navigate the complexities of modern life. Consequently, education must integrate 21st-century skills training into the curriculum. Modern education relies heavily on digital learning tools, including e-worksheets that help students understand content on devices such as computers and smartphones. According to Rusdan (2023), e-worksheets positively

impact student engagement by making learning interactive and motivating. The e-worksheet developed in this study is based on differentiated project-based learning.

PjBL integrated with STEM (Science, Technology, Engineering, and Mathematics) is well-suited for 21st-century learning (Alhayat, 2023; Prabawati, 2020; Rahmania, 2021). It fosters motivation in science and math, promotes critical thinking, and enhances cognitive skills. STEM-PjBL helps students develop essential skills, including problem-solving, collaboration, communication, and innovation. This model can also improve overall educational quality (Fitriyah & Ramadani, 2021). Project-based learning has been proven effective in boosting creativity (Widiyanti, 2021) and has a positive impact on students' creative thinking (Azzahra et al., 2023). It promotes teamwork and student collaboration (Greenier, 2020) and strengthens student engagement with their learning tasks (Pedersen, 2020).

Interviews with three physics teachers from SMA Muhammadiyah Metro, SMA Negeri Gunung Agung, and SMA Negeri 1 Katibung revealed that, although the Merdeka Curriculum has been adopted, differentiated instruction has not yet been fully implemented. For instance, the physics teacher at SMA Negeri 1 Katibung stated that while the Merdeka Curriculum is used, lessons are not yet delivered in a differentiated manner. Teachers still use traditional LKPD that are not digital or project-based and have not focused on 21st-century skill development.

A student needs analysis regarding a differentiated project-based STEM e-worksheet showed that 77.1% struggled with alternative energy lessons due to unclear explanations and incomplete material, and 62.9% lacked specific learning resources. Additionally, 84.3% believed that project tasks improved collaboration, 51.4% noted improved communication during presentations, and 46.2% felt that their critical and creative thinking skills improved through projects. Furthermore, 100% expressed a need for differentiated e-worksheets, 92.9% for creative and critical thinking components, and 91.4% for collaboration and communication features.

Despite existing studies and analyses, one key question remains: how can we design a project-based learning process that effectively develops 21st-century skills such as critical thinking, problem-solving, creativity, collaboration, and communication? This study answers that question by proposing a differentiated project-based e-worksheet using a STEM approach. This represents a novel contribution. The core research question is: How can a differentiated, project-based e-worksheet using the STEM approach on global warming and the greenhouse effect be designed to be valid, practical, and effective in fostering students' 21st-century skills? The developed e-worksheet includes three types of differentiation—content, process, and product—to meet students' varying learning needs and interests.

METHODS

This study employed a Research and Development (R&D) design and was conducted at SMAN 1 Katibung in three meetings. The sample consisted of two class groups: the experimental group used the developed project-based student worksheet, while the control group was provided with a conventional worksheet. The research utilized both test and non-test instruments in three meetings. The non-test instruments included a needs analysis questionnaire, a validity questionnaire, an implementation feasibility questionnaire, and observation sheets to assess students' collaboration and communication skills. The test instrument consisted of questions designed to evaluate students' critical and creative thinking abilities. The development design applied in this study followed the ADDIE model by Dick and Carey (2015), which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. Due to time and resource constraints, the study was

concluded at the implementation stage. Further data collection is required to complete the final evaluation and refinement of the learning product. Therefore, future research is necessary to conduct a more thorough assessment and explore the long-term effectiveness of the developed e-worksheet module.

The analysis stage is the phase in which the researcher examines the necessity of developing learning media, its feasibility, and the development requirements (Branch, 2010). The steps taken in the research and development process during the analysis stage include selecting the material to be developed based on a needs analysis. This needs analysis can be conducted by reviewing the targeted competencies and the learning objective indicators within the *Merdeka Curriculum*. The chosen material is alternative energy. This stage aims to convert the results of task analysis and concept analysis into learning outcome indicators that students must achieve. The formulation of these learning indicators is based on the core competencies and basic competencies outlined in the *Merdeka Curriculum*. The foundation for development is built through preliminary studies, relevant research, and interviews. Key aspects to consider as the basis for development include (1) analyzing students' problem-solving and creativity skills in relation to the development, (2) analyzing the learning process, (3) analyzing the potential of using smartphones as a learning medium, and (4) analyzing the need for supporting tools used in creating the learning media.

The second stage, after conducting the analysis phase, is product design. The analysis results serve as a reference in developing a differentiated project-based e-worksheet using the STEM approach, which aims to train students' 21st-century skills. In this stage, the researcher determines the learning outcomes to be developed in the differentiated project-based e-worksheet with a STEM approach, defines the material framework, and creates a matrix. Once all the materials are ready, the researcher creates a storyboard to visualize the product being developed.

The product development stage is where the product or e-worksheet designed in the previous phase is further developed. At this stage, the researcher creates the e-LKPD in detail, including content, media, and evaluation components (Branch, 2010). The content, media, and evaluation in the e-worksheet are designed to accommodate the diverse needs of students. In this development phase, several key aspects can influence the success of the product or e-worksheet development, including:1) Instructional design, which covers learning objectives design, instructional structure design, and teaching method design. In this stage, the researcher ensures that the instructional design developed in the previous phase can be effectively and efficiently implemented in the e-worksheet development. 2) Media design, which includes graphic design, audio design, and multimedia design. At this stage, the researcher ensures that the media design developed during the design phase can be implemented effectively in the e-worksheet product. 3) Learning assessment design and program evaluation design. In this stage, the researcher ensures that the evaluation design created during the design phase can be implemented effectively and efficiently in the e-worksheet development. The validation of the developed product involves expert validators in content, media, and design. If the product is declared valid, it can then be implemented or tested in the field, including trials to assess its effectiveness and practicality.

Implementation is the stage where the developed product is applied in the learning process. In this implementation phase, the researcher trials the project-based differentiated e-worksheet using the STEM approach on the topic of Alternative Energy and Its Utilization, which has been developed and validated by experts. The field trial is conducted using a quasi-experimental research design, specifically the nonequivalent control group design (Sugiyono, 2022). The learning activities in the experimental class use the PjBL-STEM learning model, which, according to Laboy-Rush (2010), includes several stages.

The first stage is reflection, which brings students into the context of a problem and inspires them to begin investigating. The next stage is *Research*, where students are guided to conduct research by exploring scientific concepts, selecting readings, or gathering information from relevant sources. This is followed by the *Discovery* stage, in which students begin to identify the learning processes, determine what they have not yet understood, and define project steps as solutions to the problem. In the application stage, students model a solution to the problem and test the designed model; based on the results, they may return to previous steps for refinement. Finally, in the communication stage, students present their models and solutions to develop communication and collaboration skills, as well as the ability to receive and apply constructive feedback.

The evaluation stage is the process of assessing the results of implementing the differentiated project-based e-worksheet with a STEM approach in real classroom learning, specifically on the topic of global warming and the greenhouse effect. In this stage, the researcher evaluates the developed product based on the outcomes obtained during the implementation phase. The purpose of this phase is to determine the practicality and effectiveness of a differentiated project-based e-worksheet using a STEM approach in delivering material on global warming and the greenhouse effect. The product outcome at this stage is a practical, effective, differentiated project-based e-worksheet with a STEM approach for the topic of Alternative Energy and Its Utilization. During the evaluation stage, several assessment instruments are used to measure 21st-century skills. To assess critical and creative thinking skills, test instruments in the form of questions are used, while for collaboration and communication skills, instruments such as questionnaires and observation sheets are employed.

The data used to determine the product's validity were collected through questionnaires (quantitative data). The questionnaires used included expert assessments of both the material and the design. The scoring system used a Likert scale based on Arikunto (2015), as shown in Table 1.

Table 1 Likert scale

Response option	Score
Very appropriate	4
Appropriate	3
Less appropriate	2
Not appropriate	1

The resulting scores were then converted to determine the quality of the developed product. The conversion can be seen in Table 2.

Table 2. Likert scale

Percentage	Score
25%-40%	Very low/ poor
40.1-55%	Low validity/ less good
55.1-70%	Moderate validity/ fair
70.1-85%	High validity/good
85.1-100%	Very high validity/ very good

Practicality data included observation sheets of the e-worksheet and student response questionnaires regarding the attractiveness and readability of the developed e-LKPD. The questionnaire results were analyzed using percentage analysis, similar to the product validity analysis. The product is considered practical if it reaches a minimum score of 60%, falling under the "moderate practicality" criterion.

The data used to measure product effectiveness was obtained from tests (quantitative data). These tests were conducted twice: pre-test and post-test. The results were analyzed using the N-Gain score to assess the improvement between the experimental and control groups. Additional statistical tests included the normality test, independent-samples t-test (to compare pre-test and post-test scores), paired-samples t-test, one-way ANOVA (to evaluate the impact of differentiated learning styles: kinesthetic, auditory, and visual), and effect size test. N-Gain scores assess the improvement in students' multi-representation abilities. The Hake (1998) formula for calculating N-Gain is presented in Table 3.

Table 3 N-Gain criteria

N-Gain	Interpretation
0.71< N-Gain < 100	High
0.30 N-Gain < 0.70	Medium
N-Gain < 0.30	Low

RESULTS AND DISCUSSION

The outcome of this research and development is a set of differentiated learning media, specifically three types of project-based student worksheets designed using a STEM approach. These worksheets aim to foster 21st-century skills among students and were implemented during the learning process. The research was carried out in several stages following an established development framework. The results for each stage are detailed below.

Analysis stage

In the analysis stage, the researcher conducted both a literature review and a needs analysis of students and teachers. This step aimed to ensure alignment between the needs of the learners and educators and the outcomes of past research. The purpose of this dual analysis was to identify any existing gaps or to confirm compatibility with prior studies, allowing the formulation of recommendations or strategies to address identified challenges or enhance existing potentials. According to the literature, studies such as *"Differentiated Learning Assisted by Student Worksheets with STEM Content on Alternative Energy Materials to Improve Science Process Skills and Creative Problem Solving"* (Sulistiani et al., 2017) support the development direction. Their findings confirmed that differentiated instruction using student worksheets improves learners' creative problem-solving skills, which aligns with this study's aim of tailoring worksheets based on different learning styles. Additionally, Nyeneng et al. (2019) showed that students who used problem-based electronic worksheets demonstrated enhanced creativity. These findings reinforced the relevance of differentiated e-LKPD in promoting 21st-century skills.

Another supporting study, by Naurah et al. (2022), validated the use of STEM-integrated modules as both effective and practical learning tools. A field study was also conducted, utilizing a Google Form survey that involved 70 students and interviews with physics teachers at SMA Negeri 1 Katibung, South Lampung. Results showed that most students felt the current teaching methods did not adequately support differentiated learning, particularly in relation to individual learning styles. Teaching was still uniform, and existing LKPD materials were generic, often sourced from textbooks or the internet, and not tailored to student needs.

Additionally, the use of STEM and explicit training in 21st-century skills was still lacking in instructional practice. The new *Merdeka Curriculum* requires teachers to develop materials that reflect differentiation principles. However, based on preliminary findings, such practices are not widely implemented. Students expressed a strong need for differentiated e-worksheets tailored to their interests, readiness levels, and learning

preferences, especially to support the development of critical thinking, creativity, collaboration, and communication.

Interviews also revealed that current classroom practices do not cater to different learning styles, which contributes to varied mastery of 21st-century skills. According to Mujito (2014) and Aprilia et al. (2022), understanding individual learning styles allows educators to design effective learning activities that promote better student engagement and comprehension. The existing generic e-worksheets do not adequately address this, leading to suboptimal development of these essential skills. To bridge this gap, the researcher developed a project-based differentiated e-worksheet with a STEM approach to accommodate various learning styles and enhance students' 21st-century competencies. The result of the analyzed stage based on Table 4.

Table 4 The result of the needs analysis of students

No.	Questions	Answer (%)	
		Yes	No
1	Do you have a textbook or other reference book to study physics?	51.4	48.6
2	Do you search for other materials besides the schoolbook to help you understand the material (e.g., from the internet)?	47.1	52.9
3	Do you find it difficult to study the subtopic of global warming and the greenhouse effect from the book (e.g., due to the completeness of the material, explanation technique, format, etc.)?	77.1	22.9
4	Do you use technology (such as a mobile phone) in your learning process?	61.4	38.6
5	Does your teacher use special teaching materials to teach renewable energy (e.g., e-worksheets, videos, visual aids, etc.)?	62.9	37.1
6	Have you ever been assigned a project by your physics teacher?	85.7	14.3
7	If yes, did the project assignment train your collaboration with group members while working on it?	84.3	15.7
8	Did the project assignment allow you to think more critically and creatively while completing it?	46.2	53.8
9	After the project was completed, were you asked to present the final result of your project?	80.0	20.0
10	If yes, did the presentation and Q&A session train your communication skills?	51.4	48.6
11	Do you experience difficulties understanding the material through the teaching materials and methods used by your teacher?	80.0	20.0
12	Do you need alternative teaching materials that can help you learn about alternative energy more easily and interestingly?	95.7	4.3
13	Do you agree that teaching materials such as e-LKPD (electronic student worksheets) should be developed and can be accessed via the internet?	94.3	5.7
14	Do you agree with the development of e-LKPD that includes learning material options according to your preferences?	100.0	0.0
15	Do you agree that e-LKPDs should be developed to train your critical and creative thinking skills?	92.9	7.1
16	Do you agree that e-LKPDs are developed to train your collaboration and communication skills?	91.4	8.6

The results of the needs analysis show that students have diverse learning styles and interests. They desire a learning process that aligns with their individual learning styles. Interview results with educators revealed that in each lesson, teachers have not yet facilitated students with learning media tailored to their learning styles. This results in differences in 21st-century skills among students. According to Mujito (2014), students' learning styles play an important role in the learning process. Therefore, educators need to

understand each student's learning style. By recognizing these styles, teachers can more easily design appropriate learning activities, which will help students receive and comprehend information more effectively (Aprilia et al., 2022). Not all students possess strong 21st-century skills, even though teachers have used worksheets designed to develop them. This is because the worksheets used have not been tailored to the individual learning style needs of the students. Hence, the researcher developed a differentiated project-based worksheet using a STEM approach to train students' 21st-century skills while accommodating the diverse learning styles of each student.

Design stage

Design of Differentiated Learning Media

In the design phase, the researcher developed a learning medium in the form of a differentiated LKPD based on the needs analyses of both teachers and students. The differentiated learning implemented in this program acknowledges that each student has unique learning needs and characteristics. Therefore, different approaches must be applied to meet their learning needs. The learning needs addressed in this program focus on students' learning styles. These learning styles are integrated into the LKPD as instructional materials that can assist students in developing their 21st-century skills. Additionally, the LKPD is designed using a STEM approach, which can further enhance students' 21st-century skills. The detailed differentiated learning program produced is outlined in Table 5.

Table 5 The aspects of the differentiated project

Dimension	Aspects	Activity	Targeted student profile
Content	Recources	Textbooks	Visual
		Article	Visual
		Video	Auditory
		Presentation (PPT)	Auditory
		The environment	Kinesthetic
	Material difficulty level	The materials are the same /homogeneous	High learning readiness
			Moderate learning readiness
			Low learning readiness
Process	Learning method	Lecture	Auditory
		Group discussion	Auditory, kinesthetic, visual
		Collaborative project	Kinesthetic
		Individual problem-solving	Auditory, visual
	Learning model	Individual problem-solving	Auditory, visual
	Strategy	Individual guidance (low intensity)	Low learning readiness
			Moderate learning readiness
			High learning readiness
		Individual guidance (moderate)	Auditory visual
			Visual
			Kinesthetic
		Use technology	Auditory visual
			Visual
			Kinesthetic

Dimension	Aspects	Activity	Targeted student profile
		STEM Approach	Auditory visual Visual Kinesthetic
	Task options	Presentation	Auditory visual Visual Kinesthetic
		Essay	Auditory visual Visual Kinesthetic
		Poster	Visual
		Video	Auditory
		Physical product	Kinesthetic
	Product format	Presentation (slide/oral)	Audiovisual, kinesthetic
		Video	Aaudio
		Poster	Visual
		Creative/physical product	Kinesthetic
	Assessment rubric	Differences in skill level and product quality	
	Reflection and feedback	Students are given time and opportunity to reflect on the product created and receive constructive feedback to help improve their work and deepen their understanding of the topic	

b. The e- Worksheet Design

The e-worksheet product developed is a project-based, differentiated e-worksheet tailored to students' learning styles and infused with STEM content on global warming, designed to cultivate 21st-century skills. The resulting e-worksheet consists of three types, each corresponding to a different student learning style: kinesthetic, auditory, and visual.

Kinesthetic e-worksheets are digital learning materials that emphasize hands-on interaction, encouraging students to engage in simulations, drag-and-drop tasks, or physical activities that align with the lesson, thereby supporting learning through movement and direct manipulation (Amtari, 2021). Auditory e-worksheets are designed to enhance comprehension through listening activities such as audio recordings, pronunciation guides, spoken instructions, or storytelling, which are especially beneficial for auditory learners (Putri, 2024). Visual e-worksheets present information using images, diagrams, charts, videos, and color-coded content to help students understand and retain concepts through visual representation, making complex ideas easier to grasp and remember (Putri, 2024).

This e-worksheet facilitates students' needs through differentiation in the dimensions of content, process, and product. Thus, during classroom instruction, teachers can simultaneously address the diverse needs of their students. The design of the e-worksheet in Figure 1a for the cover, Figure 1b for reflection, and Figure 1c for activities.

(a) (b) (c)

Figure 1 (a) Cover, (b) Reflection, and (c) Activities

Development stage

Then, the researchers began compiling and developing the student worksheet based on the previously created design. The student worksheet was created using Canva and structured according to a differentiated learning approach across the dimensions of content, process, and product. This differentiated learning approach accommodates diverse student learning needs and enables the development of 21st-century skills. The activities in the student worksheet follow the stages of the PjBL-STEM Laboy Rush learning model, which includes the steps: Reflection, Research, Discovery, Application, and Communication. The validity assessment of the developed student worksheet focused on the alignment between the student worksheet's design content and the instructional design (learning objectives design, instructional structure design, and teaching method and strategy design), media design (graphic design, audio design, and multimedia design), and evaluation design (learning assessment and program assessment design) to train students' 21st-century skills. The results of the validity assessment are presented in Table 6.

Table 6 E-worksheet validation results

No.	Aspects	Range score
1	Construct	86.00%
2	Content	87.61%
3	Language	88.97%
4	Design	85.75%
	Percentage	**87.08%**

The validation assessment results for the student worksheet, presented in Table 6, show an average of 87.08%. The average score for each component assessed in the student worksheet is above 70%, which meets the suitability criteria for the student worksheet. Based on the expert validation scores, the project-based differentiated student worksheet designed to develop students' 21st-century skills is "Highly Suitable" for teaching global warming in Phase E of Grade X in senior high schools (SMA/MA) under the Merdeka Curriculum. However, improvements suggested by the validators in certain aspects of the student worksheet should still be implemented to ensure the student worksheet is more effective when used in the learning process.

Implementation stage

The preliminary stage is the initial phase before entering the core learning activity. At this point, the teacher administers a pre-test to assess students' prior knowledge about global warming and the greenhouse effect. Students are then grouped into teams of four to five members based on their learning styles, which have been identified using a learning comfort questionnaire. Once the groups are formed, the teacher distributes student worksheets tailored to each group's learning style, as shown in Figure 2.

Figure 2 The implementation stage

In the Reflection phase, which falls under the science component of STEM, students receive both printed and digital versions of the e-worksheet. These materials include videos, texts, and illustrations that explain how plastic waste is a major contributor to global warming. The research phase, also part of the science domain, encourages students to gather information from various sources, such as the internet, to discover potential solutions to the impact of plastic waste in their local environment. This enables them to think critically and explore practical solutions to address environmental challenges, as illustrated in Figure 3.

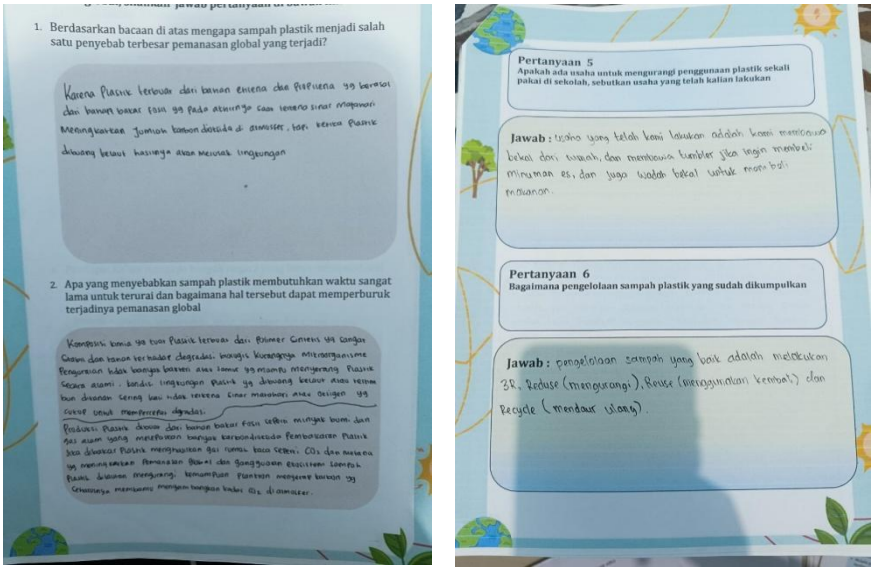

Figure 3 The result of the reflection section

The Discovery phase, under engineering, guides students in sketching project ideas and articulating how their designs connect to those ideas. In the application phase, which involves technology and engineering, students test their developed products while

integrating STEM elements. This stage promotes 21st-century skills, especially for kinesthetic learners, by engaging them in hands-on activities. In this phase, students' critical thinking skills become evident, particularly in advanced clarification and the use of strategies and tactics. Creativity is measured through students' elaboration and originality, while communication and collaboration are encouraged within group work. In the communication phase, students present their projects and explain the results of their experiments. This phase focuses on practicing 21st-century communication and teamwork skills. The final products produced by each learning style group vary: kinesthetic learners created ecobricks using plastic waste (although imperfections were noted), visual learners designed posters, and auditory learners produced informational videos about the plastic waste crisis and proposed solutions to mitigate global warming. The result of the application and communication activities is shown in Figure 4.

Figure 4 Application and communication activities

Evaluation Stage

At the evaluation stage, the practicality of the learning media was assessed using an observation sheet that evaluated the implementation of the e-worksheet during the learning process, as described in Table 7.

Table 7 The reflection

Observation aspect	Score	Criteria
Delivering learning objectives	92%	Very good
Presenting the energy crisis phenomenon through videos and images	90%	Very good
Asking basic questions to motivate students	90%	Very good
Reflection phase	92%	Very good
Research phase	88%	Very good
Discovery phase	81%	Very good
Application phase	88%	Very good
Communication phase	87%	Very good
Assisting students during activities	88%	Very good
Collecting student work for portfolio assessment	90%	Very good
Concluding the lesson and providing a summary	93%	Very good
Average	89%	
Criteria	Very good	

Based on the implementation analysis of the e-worksheet, the average percentage score was 89%. This score falls within the "Very Good" category; thus, it can be concluded that the e-worksheet developed in this study can be practically used for differentiated learning

in Grade 10 under the Merdeka Curriculum. The results of students' critical thinking skills, based on pre- and post-tests, are shown in Figure 5.

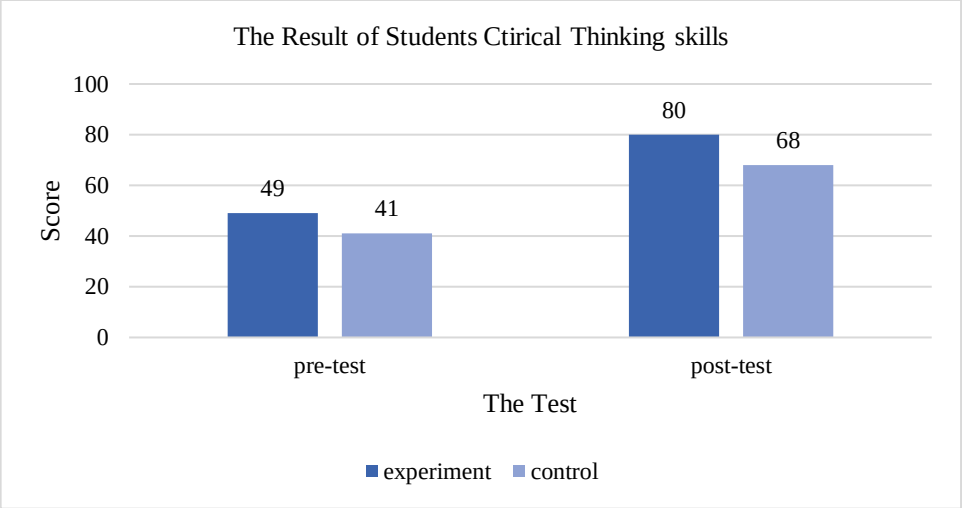

Figure 5 The result of students' critical thinking skills

Based on the graph of critical thinking skills, the average N-Gain score for critical thinking in the experimental class is higher than that of the control class. This indicates that the critical thinking ability in the experimental class, after using the differentiated project-based e-worksheet, is greater than that in the control class, which used the conventional e-worksheet, with an N-Gain score categorized as “moderate.” From these results, it can be concluded that the differentiated project-based e-worksheet is effective in training students' critical thinking skills. In line with that, the results of students' creative thinking skills are shown in Figure 6.

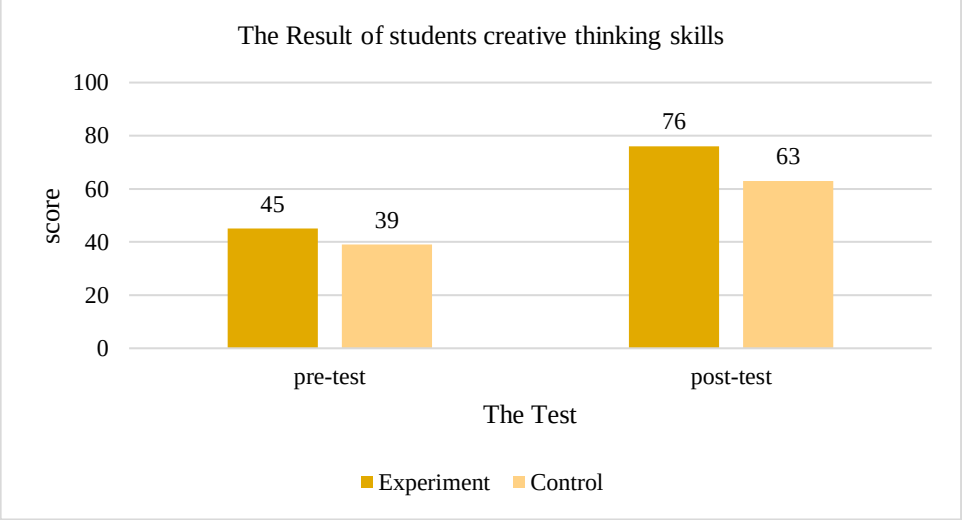

Figure 6 The result of students' creative thinking

Based on Figure 6, the average N-Gain score for creative thinking in the experimental class is higher than that of the control class. This indicates that the creative thinking ability in the experimental class, after using the differentiated project-based e-worksheet, is greater than that in the control class, which used the conventional e-worksheet. From these results, it can be concluded that the differentiated project-based e-worksheet is effective in training students’ creative thinking skills. The results of the

paired-samples t-test show that Sig. (2-tailed) value is 0.001 < 0.05 for kinesthetic, auditory, and visual learning styles. This indicates that, after implementing differentiated learning tailored to each learning style, there was a significant improvement in creative thinking skills. Therefore, the use of project-based e-worksheets with a differentiated approach for each learning style has proven to be highly effective. The results of communication and collaboration skills are shown in Table 8.

Table 8 The result of communication and collaboration skills

Classes	Average score of communication	Average score of collaboration
Experimental	83.4	87.37
Control	74	78.65

The data show the average scores for students' communication skills in both the experimental and control groups before and after the intervention. In the experimental group, the average score increased from 83.4 to 87.37, indicating an improvement in students' communication abilities after using the differentiated project-based e-worksheet. Meanwhile, the control group also experienced an increase, from 74 to 78.65, but the improvement was smaller compared to the experimental group. This suggests that the differentiated approach used in the experimental group had a more substantial impact on enhancing students' communication skills than the conventional method applied in the control group. The results of the paired sample t-test on creative thinking learning outcomes are described in Table 9.

Table 9 The results of the paired sample t-test on creative thinking learning outcomes

Learning Style	N	Pre-test Mean	Post-test Mean	R (correlation)	Difference	Sig.
Kinesthetic	13	44.5	78.6	0.949	29.6	0.001
Auditory	14	46.5	78.0	0.937	27.0	0.001
Visual	11	42.0	72.8	0.907	28.5	0.001

Based on the analysis presented in Table 9, the average post-test scores are higher than the pre-test scores across all learning style groups. The correlation within each group is very strong, and a clear difference is evident between the pre-test and post-test scores. The paired-samples t-test results show that Sig. (2-tailed) value is 0.001 < 0.05 for kinesthetic, auditory, and visual learning styles. This suggests that, following the implementation of differentiated learning tailored to each student's learning style, there was a significant improvement in creative thinking skills. Therefore, the use of project-based e-worksheet with a differentiated approach for each learning style is proven to be highly effective. The result of the effect size test is described in Table 10.

Table 10 The results of the effect size test on critical thinking and creative thinking

F	*Df*	*Sig.*	*Partial Eta Squared*
64.596	1	0.001	0.469
30.369	1	0.001	0.294

The results show a significance value of 0.001, which is less than 0.05. This indicates that the implementation of differentiated project-based e-worksheets had a significant effect on students' learning outcomes in the experimental class compared to the control class. The partial eta-squared value of 0.469 suggests that the effect of using the differentiated e-worksheet in the experimental class falls within the moderate range**.** Similarly, the second result also shows a significance value of 0.001 < 0.05, indicating a significant influence of the e-worksheet on students' learning outcomes in the experimental class. The partial eta squared score of 0.294 also places the effect in the moderate range**,**

suggesting that differentiated e-worksheets contribute moderately to improving students' critical and creative thinking skills.

The research findings indicate that the use of differentiated project-based student worksheets with a STEM approach significantly improves students' collaboration skills. This is demonstrated by comparing collaboration skill scores between the experimental and control classes, where students in the experimental group—those who learned using the differentiated student worksheet—achieved better collaborative outcomes. These findings are further supported by statistical tests, which revealed a significant difference between the two groups, indicating the effectiveness of the instructional approach in fostering students' ability to work actively together, support each other, and complete tasks efficiently.

Furthermore, tests on students with different learning styles (visual, auditory, and kinesthetic) showed no significant differences in the improvement of collaboration skills. This suggests that the differentiated e-worksheet effectively accommodated diverse learning styles, providing all students, regardless of their preferred style, the same opportunity to develop their collaboration skills. Hence, the differentiated e-worksheet serves as an inclusive learning tool that not only emphasizes content but also the development of students' soft skills. Theoretically, this outcome aligns with Tomlinson's (2001) perspective, which posits that differentiated instruction is designed to adjust learning processes according to students' individual needs, including their interests, readiness, and learning styles. Such an approach promotes active student engagement and encourages effective collaboration in completing tasks. The PjBL model used in developing this e-worksheet is widely known for its effectiveness in enhancing collaboration skills. According to Andriani (2016) PjBL encourages students to work in teams, solve real-world problems, and share roles and responsibilities—key components of collaboration. In science education, such as physics, collaboration is essential, as many activities, including experiments, discussions, and project presentations, require teamwork.

These findings are consistent with prior research by Nasrullah et al. (2018), which showed that e-worksheet use in physics education can actively engage students and foster peer collaboration. The e-worksheet acts not only as a task guide but also as an effective tool for facilitating teamwork, providing systematic steps that encourage discussion, interaction, and role division within groups. The Partnership for 21st Century Skills (Usprianti, 2021) emphasizes that collaboration is a crucial competency that should be developed in school, as it is highly required in the future workforce, especially in interdisciplinary team settings. In this context, the differentiated project-based e-worksheet, using a STEM approach, not only develops students' cognitive skills but also prepares them to face complex social and professional challenges. Similarly, findings from Mardlatillah & Sa'adah (2022) reveal that instruction tailored to students' learning styles content, process, and product enhances learning quality. Students also tend to prefer instructional materials that include enjoyable activities, such as e-worksheets. This is supported by Setiadi et al. (2020), who concluded that the use of e-worksheet can boost student activity and learning motivation.

CONCLUSION

The differentiated project-based e-worksheet, utilizing the STEM approach, is designed to develop 21st-century skills. It includes project-based learning activities across five phases: reflection (understanding problems), research (developing ideas), discovery (processing solutions), application (testing the product with STEM links), and communication (presenting the results). Three types of e-worksheets were developed based on students'

learning styles: kinesthetic, auditory, and visual—using texts, images, videos, and evaluations. The e-worksheet was validated by experts, achieving a high validity score of 87.08%, which indicates that it is highly valid and suitable for classroom use. The practicality of the e-worksheet is demonstrated by its successful implementation (89%) and positive student responses regarding readability (89.2%) and attractiveness (87.4%), making it highly practical. These results are attributed to student worksheet activities that encourage students to practice 21st-century skills through projects tailored to their individual learning styles. Improved student skills prove the effectiveness of the e-worksheet. Critical thinking skills increased, with an average n-gain of 0.61 in the experimental class versus 0.46 in the control class ($p = 0.001$; moderate effect size = 0.469). Creative thinking also improved (0.56 vs. 0.39, sig. 0.001, effect size 0.294). Communication skills were better in the experimental class (83.4 vs 74), and collaboration improved as well (87.37 vs 78.65), both with a significance of 0.001. In conclusion, the differentiated project-based e-worksheet with a STEM approach is valid, practical, and effective in enhancing students' critical thinking, creativity, communication, and collaboration skills. The findings imply that implementing differentiated project-based e-worksheets with a STEM approach can significantly enhance students' 21st-century skills by aligning learning activities with their individual learning styles. This approach offers a practical, effective instructional model that educators can adopt to foster critical thinking, creativity, communication, and collaboration across diverse classroom settings.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

All authors have contributed to the conceptualization, methodology, formal analysis, investigation, and writing of this article.

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AUTHOR PROFILE

Siti Aisyah is from metro, lampung. She is a postgraduate student of lampung University. Email: sitiaisyah041217@gmail.com

Agus Suyatna is an expert in developing learning media in physics and science education, focusing on training and improving students' skills. Email: agus.suyatna@fkip.unila.ac.id

Viyanty is an expert in developing learning instruments in physics education to assess students' abilities. Email: viyanti.1980@fkip.unila.ac.id