Research Article

Cultivating Environmental Sustainability Awareness in Students Through ECO-SETS: Implementation of Science, Environment, Technology, and Society (SETS)-Based Worksheets on Climate Change Topics

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Article Info

ABSTRACT

Purpose of the study: This study aims to develop the ECO-SETS Worksheet (Environment and Climate Oriented through Science, Environment, Technology, and Society), an innovative student worksheet that integrates the SETS approach with simple coding simulations to train students' ESA on climate change topics.

Methodology: The research employed the ADDIE development model, consisting of five stages. The study involved Grade X and XI students from several schools in South Sumatra. Data collection included teacher interviews, expert validation by three experts, student practicality questionnaires involving nine students, and effectiveness testing through pretest–posttest assessments with 60 respondents. Instruments consisted of Likert-scale questionnaires, open-ended feedback forms, and concept mastery tests. Data were analyzed using the Guttman scale for validity, the Likert scale for practicality, and N-gain and t-tests for effectiveness.

Main Findings: The results indicate that ECO-SETS LKPD is highly valid, with average validation scores of 90.7%, and very practical, with student response scores of 97.14% (one-to-one trial) and 96.50% (small-group trial). In terms of effectiveness, the LKPD significantly improved students' environmental sustainability awareness, evidenced by an N-gain score of 0.65 in the experimental class and statistically significant differences compared to the control group.

Novelty/Originality of this study: The novelty of this study lies in the integration of SETS-based contextual learning with simple coding simulations within a structured LKPD framework, bridging environmental education and computational thinking. This integrative approach not only strengthens conceptual understanding but also equips students with adaptive skills to address real-world environmental challenges, offering a new direction for sustainable science education.

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1.   INTRODUCTION

Sustainable development is defined as a conscious and planned effort that integrates environmental, social, and economic aspects into development strategies to ensure the integrity of the environment as well as the safety, capability, well-being, and quality of life of present and future generations [1], [2]. The UN has declared the Decade of Education for Sustainable Development, also known as DESD. The goal of this Education Sustainable Development decade is to integrate the values of sustainable development into all aspects of learning to promote behavior change towards a more sustainable and just society for all [3], [4]. In the 21st century, it has also become evident that education is crucial for promoting sustainable development. ESD demonstrates that education plays an essential role in achieving the SDGs and sustainability because of its close ties to various points within the SDGs, such as how the level of education can lift people out of poverty (1st SDG), lead to better job opportunities (SDG 8), or provide a broad and extensive understanding of the impacts of climate change (13th SDG) [5], [6].

Environmental sustainability awareness is a continuous awareness of the environment surrounding students, or it can also be described as an awareness to protect and appreciate the environment and life around them [7], [8]. One way to foster sustainability awareness is to conduct teaching and learning activities using an ESD approach and problem-based learning models, as well as choosing topics that are in line with the three pillars of ESD [3], [9]. This is in line with what previous studies have explained, namely that the implementation of education programs for sustainable development aims to foster awareness, attitudes, and values that can serve as a foundation for successful sustainable development. This includes learning processes on how to make decisions that take into account the long-term economic, ecological, and equality aspects for all humans [10]-[12].

In the world of education, students' understanding of climate change is still relatively low. Several studies confirm that conventional teaching methods that focus on delivering theory are often ineffective in engaging students [13], [14]. The lack of hands-on exploration and minimal interaction in learning makes it difficult for students to connect the concept of climate change with the phenomena they encounter in their daily lives [15]-[17]. Based on interviews with teachers and analysis of several students at public high schools in South Sumatra, it was found that students' understanding of climate change material is still relatively low. This is evidenced by the students' initial ability tests: 5 students met the criteria, and 18 had low understanding. There were 9 students who were deficient in the sub-material on climate change mitigation, 6 students who were deficient in the sub-material on climate change mitigation implementation, and 3 students who were deficient in problem-solving related to climate change utilization. This is due to the lack of contextual teaching materials that are able to relate scientific concepts to real phenomena around them. Teachers also said that learning is still predominantly centered on textbooks, so students are less actively involved in the learning process. Therefore, there is a need for innovative learning media that is not only visually appealing, but also allows students to explore and interact directly with the concepts being studied. One solution that can be applied is student worksheets (LKPD) that can train environmental sustainability awareness and are analysis-based.

One approach that can be applied to foster environmental sustainability awareness is the SETS approach. SETS-based learning can be used to foster environmental sustainability awareness in students [18], [19]. There are five stages in the SETS approach, namely the invitation and exploration stage to train the ability to identify phenomena scientifically, the solution and application stage to train the ability to evaluate and design scientific investigations, and the application and concept consolidation stage to train the ability to interpret scientific data and evidence [20]-[23]. The SETS (Science, Environment, Technology, Society) approach is one that places students at the center of learning, training them to think universally and solve problems by connecting various concepts they have previously learned from related fields of science [20]-[25]. The SETS approach is a learning model that is well suited to utilizing environmental pollution as an interesting learning topic for students [26]-[28]. The use of the SETS approach can facilitate teachers and students in finding solutions to contextual environmental issues, thereby having a positive impact on students' understanding [29], [30]. This is in accordance with the decision of the head of the Ministry of Education and Culture's Standards, Curriculum, and Assessment Agency No. 008/H/KR/2022 regarding learning outcomes for physics phase E in the independent curriculum, which requires students to have the ability to create solutions to problems based on local, national, or global issues related to understanding environmental change [31]-[33].

Climate change education therefore is not merely about imparting knowledge; it is pivotal in shaping students' awareness and attitudes towards a pressing global issue. Recent surveys involving university students reveal a dichotomy wherein a majority recognize climate change as an authentic concern while simultaneously holding numerous misconceptions about its implications [8], [34]. This underscores the necessity for targeted educational strategies that correct these misconceptions while enhancing comprehension of climate science. By utilizing collaborative and project-based learning methods, educators can significantly increase teacher competence and adaptability in navigating these complex curricula [35], [36]. However, research related to the development of SETS (Science, Environmental, Technology and Society)-based Student Worksheets, particularly on the topic of climate change, assisted by simple coding simulations in Indonesia, has not been

widely conducted and published in reputable national journals, which is the background for planning this research. Based on this background, there is a need for SETS-based Student Worksheets Assisted by Simple Coding Simulations to Train Students' Environmental Sustainability Awareness through the term ECO-SETS (Environment and Climate Oriented through Science, Environment, Technology, and Society).

Environmental Sustainability Awareness is a form of awareness manifested through understanding and concern for social and economic environmental issues related to sustainability. Individual awareness of the importance of maintaining a balance between current and future needs, as well as actions that can be taken to minimize negative impacts on the environment and society. There are three categories of sustainability: sustainability practice awareness, behavioral and attitude awareness, and emotional awareness. To cultivate Environmental Sustainability Awareness, appropriate teaching materials are needed, especially in teaching topics related to climate change. Several previous studies have developed interactive media and teaching materials using various approaches, such as the use of student worksheets to improve science literacy [37], [38] digital integration in SETS-based student worksheets to increase learning motivation , and the implementation of the SETS approach through learning media focused on improving student learning outcomes [39]-[41]. However, there is still little research that specifically integrates simple SETS-based coding simulations into student worksheets to train Environmental Sustainability Awareness. Therefore, the state of the art is through the development of worksheets that integrate simple coding simulations with the scratch method, which combines animation and interactivity in one platform and can be easily simulated by students.

Based on the results of field observations, interviews, and focus group discussions with school principals and teachers, the main problems identified in physics education on renewable energy at public high schools in South Sumatra were formulated as follows: (1) How to develop ECO-SETS as a valid and practical SETS-based student worksheet for teaching climate change?; and (2) How effective is ECO-SETS as a SETS-based LKPD in training environmental sustainability awareness in learning about climate change?

2.   RESEARCH METHOD

This study was conducted using the ADDIE development model. This development model aims to design and develop interventions (such as programs, products, teaching and learning strategies, learning processes, learning systems, learning environments, and the like) with the aim of developing or validating theories. Therefore, the development model in this study can be said to be a development method for developing a product in the form of student worksheets. The subjects of this study were students in grades X and XI in South Sumatra in the 2025/2026 academic year.

In the analysis stage, researchers conducted preliminary studies including a) observation of learning implementation, tools, media, and learning materials, b) observation of problems during learning, c) analysis of students' 21st century skills profiles, and d) interviews with teachers and students. The results of the preliminary study were used as a basis for mapping the needs for developing ECO-SETS LKPD. The research continued with the design stage. At this stage, the researchers designed the initial ECO-SETS worksheets. The design was based on the results of the needs analysis. This process included a) storyboard design, b) preparation of research instruments, including validation sheets, questionnaires, and pretest-posttest questions, and c) design in accordance with the concept of climate change material. The next stage was the development stage. At this stage, the researchers produced prototype I based on the storyboard in accordance with the learning objectives. The prototype produced was validated by experts to assess its feasibility and obtain suggestions for revision. The product of expert validation was Prototype II. The final stage was implementation. At this stage, researchers conducted limited trials on a small group at a school in South Sumatra (30 people) to assess the practicality of the ECO-SETS worksheet.

The limited trial was conducted using the Quasi-Experiment method with Experiment and Controll Class design. The product of the limited trial was Prototype III. After that, a large-scale trial was conducted to measure the effectiveness of the ECO-SETS LKPD. The large-scale trial was conducted in three schools in South Sumatra using the Quasi-Experiment method with a One-Group Pretest-Posttest design. At this stage, researchers conducted on large group at a school in South Sumatra (60 people) to know the effectiveness of the ECO-SETS worksheet. The instrument provided was an essay consisting of eight questions, validated with a score of 80.5, which is considered high. In addition, a questionnaire was used to analyze how students' awareness of climate change in their environmental sustainability awareness had changed. The questionnaire has been validated for content and format, with an average score of 87.8, indicating validity and suitability for research purposes. This study was conducted through five stages according to the ADDIE development model, namely Analyze, Design, Development, Implementation, and Evaluation, with the following design in figure.
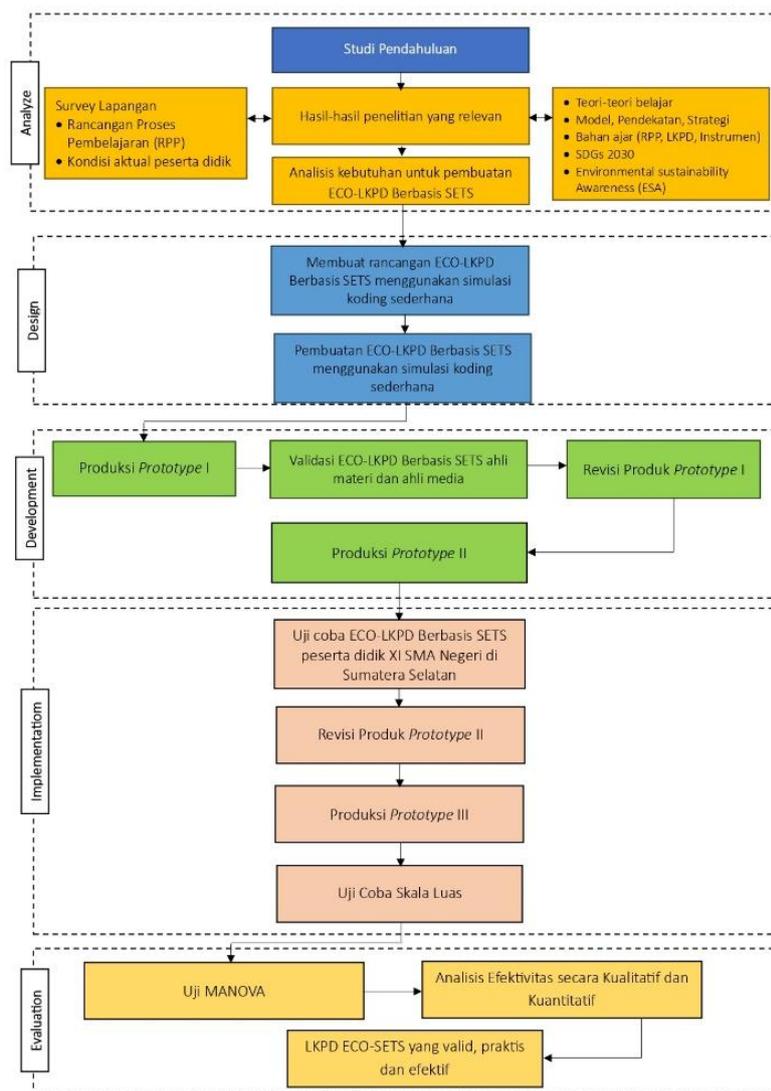
Figure 1. ADDIE Research Design

3.   RESULTS AND DISCUSSION

The validation of SETS (Science, Environment, Technology and Society)-based LKPD on climate change material was carried out by three lecturers, consisting of one lecturer as a media expert validator and two lecturers as material expert validators. Based on the subject matter expert validation assessment of SETS-based LKPD on climate change material, nine indicators were analyzed, namely Student Worksheets (LKPD), conceptual accuracy, material suitability, independent curriculum content, question feasibility, use of language appropriate to student development, material presented with titles and in a simple manner, completeness of LKPD, clear learning objectives, and SETS-based. In the media expert validation assessment, two indicators were analyzed, namely the use of letters and writing and attractive Student Worksheets (LKPD). In this study, after validation by experts, the next assessment was carried out by 3 physics teachers. After that, the product was tested on grade XII MIPA students using SETS-based LKPD (Science, Environment, Technology, and Society) on climate change.

Research on the development of Student Worksheets (LKPD) based on SETS (Science, Environment, Technology, and Society) to train students in Environmental Sustainability Awareness (ESA). This research uses the ADDIE development model, which consists of 5 stages, namely Analyze, Design, Development, Implementation, and Evaluation[42]. This initial stage began with a needs analysis to identify the background issues underlying the importance of developing learning media. Researchers identified gaps between existing learning conditions and student needs, both in terms of conceptual understanding and the use of learning media appropriate to the characteristics of 21st-century students. Data was collected through interviews with subject teachers and the distribution of questionnaires to students to determine their interests, learning difficulties, and

expectations regarding technology-based learning media. The results of this analysis were used as the basis for formulating the objectives and direction of product development.

Based on interviews with teachers and analysis of several students at public high schools in Palembang, it was found that students' understanding of global warming is still relatively low. This is exacerbated by the lack of interactive and contextual learning media that can link scientific concepts to real phenomena around them. Teachers also said that learning is still predominantly centered on textbooks, so students are less actively involved in the learning process [43]. This condition poses a challenge in efforts to train students in Environmental Sustainability Awareness (ESA). Therefore, there is a need for innovative learning media that is not only visually appealing, but also allows students to explore and interact directly with the concepts being studied.

A needs analysis was also conducted using a Google Forms-based questionnaire distributed to several high schools in Palembang. The respondents who filled out the questionnaire were 11th grade students. Based on the needs analysis conducted through the distribution of questionnaires to 11th grade students, it was found that the development of SETS-based LKPD with simple coding assistance was needed to train Environmental Sustainability Awareness (ESA). The research was strengthened by several factors, namely: 1) there were no SETS-based LKPDs with simple coding available, 2) in general, the majority (100%) of students had access to ICT devices that supported the use of digital LKPDs and simulations, 3) 94% of respondents agreed that it was necessary to develop SETS-based LKPD on climate change material to train Environmental Sustainability Awareness (ESA). The curriculum currently used in high schools is the independent curriculum. This curriculum is also used as a guide in developing LKPD on climate change material [44]. The main sub-topics discussed are the definition of climate change, human activities that contribute to climate change, the impact of climate change on the environment, and concrete actions that can be taken to prevent massive climate change.

After analyzing the problem, curriculum, and material, the researcher designed a solution, namely creating a worksheet development design. This development began with mapping the learning objectives to be achieved in the climate change material. The LKPD developed discusses the definition of climate change, human activities that contribute to climate change, the impact of climate change on the environment, as well as concrete actions that can be taken to prevent massive climate change and technologies that can be used by students related to climate change material based on the SETS stages. The LKPD design was created in A4 size (21x29.7 cm). The E-LKPD development was designed using Canva. The images and illustrations created have been tailored to the needs of students. Images, illustrations, embedded Google Collabs, and coding blocks have been designed to provide a realistic picture to students so that they can better understand the concepts presented in the material. The researcher created the cover design using Canva. The cover of the LKPD developed is titled "Climate Change Student Worksheet" and contains illustrations related to the material to be studied, namely climate change. The use of a combination of red and orange colors indicates that human activities have a significant impact on climate change.

Figure 2. SETS-based LKPD development design Front cover

After the front cover, page one contains an introduction, table of contents, learning outcomes, and instructions for using the LKPD, which can help students access the SETS-based LKPD. Each page is designed with a combination of colors, taking into account the clarity of the colors and providing a background that is not too dominant.

Figure 3. SETS-based LKPD development design Contents section

On page four, instructions for the upcoming lesson are provided. It begins by asking students to prepare writing instruments such as pens, paper, and gadgets or laptops. Students are asked to read and understand each passage in the SETS-based LKPD, and to actively ask the teacher questions if there is anything they do not understand, as shown in Figure 4.

Figure 4. SETS-based LKPD development design Contents section

The next page is the section on the material discussed. The material presented is also adapted to the SETS stages. It begins with an introduction that starts by presenting current issues in society, namely information about global issues concerning air pollution and community activities that contribute to climate change. Students are presented with several news articles discussing the findings of microplastics in rainwater, sources of pollution, their impact on health and the environment, and the responses of the community and researchers. Another illustration is an aerial photo of a densely populated urban area, showing tightly packed buildings and little green space. The articles discuss the causes of the Urban Heat Island effect, its impact on city temperatures, the role of infrastructure development, and the need for environmentally friendly solutions. The LKPD display is shown in Figure 5.
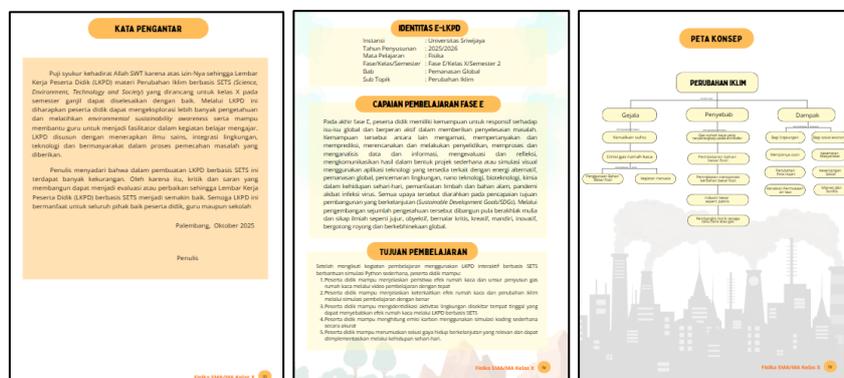

Figure 5. SETS-based LKPD development design Contents section

The next page discusses introductory material for activities that students read in order to proceed to group discussions. Exploration is a stage of the SETS approach that involves collaborative activities for students so that they are able to engage in full discussions by searching for updated references and answering questions on the worksheet. The instructions for the exploration activity are as follows: In our daily lives, we often see human activities in urban and rural areas. In your opinion, do these activities have an impact on global climate change? Let's explore this in depth through the activities in this worksheet. The exploration section is shown in Figure 6.
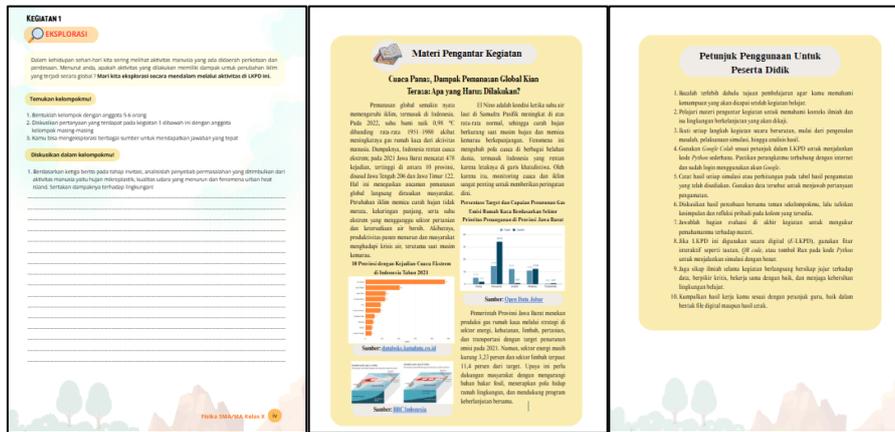

Figure 6. SETS-based LKPD development design Exploration section

Simple coding integration in SETS-based LKPD is demonstrated on the introduction page to Python and Google Collabs, as well as the use of Pictoblox. The use of simple coding is part of the learning process presented with the SETS approach, which correlates with the problem-solving stage through solutions that can be provided and simulated. In the LKPD, students are given three practical activities. The first practical activity presented is Daily Carbon Footprint: Simple Calculator with the learning objective that students are able to use the Python programming language through Google Colab to accurately calculate the carbon footprint of transportation activities, electricity consumption, and eating patterns. The practical activity is shown in Figure 7.
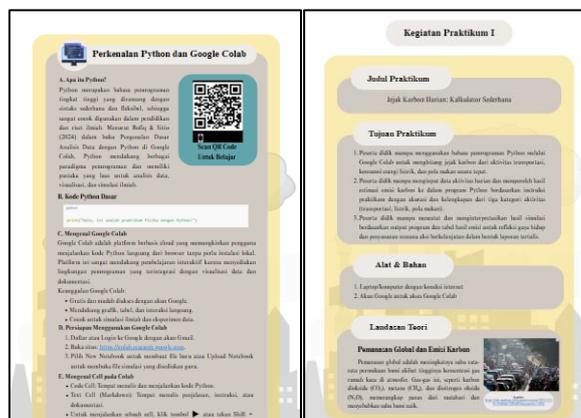

Figure 7. SETS-based LKPD development design for the practical section

The researchers designed and created LKPD based on the results of their analysis. At this stage, the researchers designed digital-based LKPD using Canva. In addition, at this stage, the researchers also developed expert validation instruments to validate the SETS-based LKPD that had been developed.

The initial LKPD product that has been designed will enter the development stage. The purpose of this step is to ensure that the LKPD product is much better before it is implemented for students. The final product will be obtained after undergoing validation testing by experts in material, media, and learning aspects. In this study, validation was carried out by lecturers who are experts in material, media, and learning, as well as education practitioners, namely 11th grade teachers. The media aspect includes the design, content, and language used in SETS-based LKPD. After the LKPD has undergone a validation process by experts, revisions will be made according to the results of the expert validators' assessments and the input provided. Once completed, implementation or trials will be carried out with 10th grade high school students.

The next validation test was conducted by expert validators in the field of physics. The material aspects referred to in this study relate to the suitability of the material contained in the LKPD with the learning objectives set, the accuracy of the material, the technique of presenting the material, its relevance to everyday life, and its suitability with the SETS approach. The validators in this study were lecturers who were experts in LKPD development and subject matter experts in the physics education study program at Sriwijaya University. To ensure the validity of the developed product, an expert review process was carried out, covering three main components: subject matter, media, and implementation. The walkthrough technique was used as an approach to collect data from experts, while the assessment analysis was conducted using a Likert scale. A summary of the validation results from the experts is presented in Table 1.

Table 1. Results of Content Expert Validators

Indicator	Question Amount	Score	Maximum Score	Score Percentage
Alignment with learning outcomes and learning objectives	3	15	15	100%
Suitability to the needs of students	3	15	15	100%
Suitability for teaching materials	3	15	15	100%
The truth of the substance of learning materials	2	9	10	90%
The suitability of practice questions and formative tests with learning objectives	1	4	5	80%
Benefits for expanding knowledge	3	14	15	93%
Average EVR Category				93.8%

In Table 1, the content/material aspect obtained an average percentage of 93.8%, which is classified as highly valid. This is indicated by 100% on the indicators of learning achievement suitability, student needs, and teaching material needs; 90% on the accuracy of material substance; and 80–93% on the indicators of practice questions, formative tests, and the benefits of increasing knowledge. These findings indicate that E-LKPD is considered to have met academic feasibility, relevance to the curriculum, and adequacy of content as teaching material. These results are in line with the findings of [45], which show that digital teaching materials with a systematic content structure and relevance to learning usually obtain a highly valid category from material validators. A similar study [46] on the development of STEM-based LKPD also reported high validity scores (>90%) in terms of material, especially when the material was linked to real-world contexts such as the environment and technology.

Table 2. Results of Teaching Material Design Expert Validation

Indicator	Question Amount	Score	Maximum Score	Score Percentage
Clarity of the objectives to be achieved	1	4	5	80%
Order of presentation	1	4	5	80%
Motivation	1	3	5	60%
Completeness of information	3	12	15	80%
Use of fonts (type and size)	2	7	10	70%
Layout	2	8	10	80%
Illustrations, drawings, and photographs	2	7	10	70%
Display design	1	4	5	80%
Average EVR Category				75%

In Table 2, the instructional material design aspect received an average score of 75%, placing it in the valid category. The indicators that received lower scores were motivation (60%) and font and illustration use (70%). This indicates the need for revisions in visual aesthetics, readability, and the presentation of motivational stimuli for students. These findings are which states that in the early stages of digital teaching material development, the design aspect often receives a lower score than the material aspect. This is because visual

design requires technical adjustments such as layout, font consistency, image quality, and navigation clarity. Research on the development of E-LKPD by [47] also shows that the design aspect often requires revisions related to the neatness of the layout and the quality of the illustrations before being used in the trial stage.

Table 3. Results of Language Expert Validation of Teaching Materials

Indicator	Question Amount	Score	Maximum Score	Score Percentage
Readability	4	18	20	90%
Clarity of information	2	8	10	80%
Compliance with the rules of proper and correct Indonesian language	2	9	10	90%
Effective and efficient use of language	2	10	10	100%
Average EVR Category				90%

The linguistic aspect received an average score of 90%, falling into the highly valid category. This can be seen from the 100% score for the indicators of language effectiveness and efficiency, 90% for readability and linguistic appropriateness, and 80% for clarity of information. This shows that the language aspect in E-LKPD is effective, communicative, and follows good Indonesian language rules, with some minor adjustments such as typo corrections, numbering, and command structure. Research by [21] and [48] states that E-LKPD that uses straightforward, communicative, and easy-to-understand language tends to obtain high validity in terms of language. The use of consistent and grammatically correct language is a key requirement for digital teaching materials intended for high school students. In general, the expert validation results (EVR) for each aspect were 93.8% for Content/Material, 75% for Teaching Material Design, and 90% for Teaching Material Linguistics. Thus, the average HVA was 86.27%, which is classified as highly valid and ready for testing. In addition to the Likert scale assessment, the researchers also requested comments and suggestions from experts for product improvement, which can be seen in Table 4.

Table 4. Validator Comments and Suggestions During the Expert Review Stage

Aspect	Comments and Suggestions	Follow-up
Content/Material	1. Explanation of emissions and their impact on the environment 2. Add information on the emission factors of each material and valid sources 3. What are the criteria for low, medium, and high emission categories?	Suggestions accepted and revised
Teaching Material Design	1. Correct the spelling of English terms 2. Change it to a table of contents, and provide instructions for use/completion 3. Enlarge the image and its resolution 4. Improve the learning objectives based on the ABCD rules 5. Python first, then Google Colab 6. Fix the spacing 7. Correct the website source citation 8. Improve the global average temperature by providing comparisons from valid sources 9. Add student instruments and their grids	Suggestions accepted and revised
Language of Teaching Materials	1. Photo of E-LKPD presentation instructions 2. Typo 3. Subtitle titles are numbered 4. Use of words at the beginning of sentences 5. The order of command words must be balanced 6. Tables in boxes should not be changed to bullet points	Suggestions accepted and revised

Based on the comments and suggestions provided, it can be concluded that the E-LKPD with the use of coding based on a sustainable environment regarding global warming is suitable for testing after being revised in accordance with input from validators. Research at this stage has not yet been conducted, but a limited trial has

been planned for one class at a public high school in South Sumatra. A large-scale trial will then be conducted in two classes in South Sumatra. The large-scale trial will be conducted using the Quasi-Experiment method with a One-Group Pretest-Posttest design. To measure the practicality of the ECO-SETS E-LKPD on climate change and renewable energy based on the SETS (Science, Environment, Technology, and Society) approach, a One-to-One Trial was conducted involving three 11th grade students at a public high school in South Sumatra. Students were asked to study the E-LKPD that had been revised according to the suggestions in the previous stage and to participate in the available activities, such as analyzing the phenomenon of global warming, simple coding simulations of the greenhouse effect, and contextual exercises related to renewable energy and climate change issues [49], [25]. After that, they filled out an assessment questionnaire to provide feedback on the practicality of the E-LKPD. The results of the assessment in the One-to-One Trial stage by the students can be seen in Table 5.

Table 5. Results of Student Questionnaire Assessment in the One-to-One Trial Phase

No	Student Initials	Total Score	Maximum Score	HEOS	HEOS Percentage
1	A.W.W	68	70	0.97	97.14%
2	M.H.A	66	70	0.94	94.28%
3	D.F	70	70	1	100%
Average HEOS in the One-to-One Trial stage					97.14%
Category					Very Practical

Based on the data in Table 5, the average HEOS in the One-to-One Trial stage was 97.14%. Individual scores showed that all three students had a very high level of practicality with HEOS percentages of 100%, 97.14%, and 94.28%, respectively, thus classified as practical. These findings indicate that the ECO-SETS E-LKPD on the topic of climate change and renewable energy based on the SETS approach that was developed has an excellent level of practicality. After prototype 1 was declared valid and practical through the Quasi-Experiment and One-to-One Trial assessment methods, the researcher revised the prototype based on the suggestions and comments received, resulting in prototype 2. The revised prototype was then tested in a small group during a Small Group Trial to assess its practicality. The trial was conducted on ten grade XI students at a South Sumatra State Senior High School, using the same instrument as in the One-to-One Trial stage. After the trial, students were asked to complete a questionnaire. Table 6 presents the results of the student questionnaire regarding the use of prototype 2.

Table 6. Student Assessment Results at the Small Group Trial Stage

No	Students Initial	Score Amount	Score Maximum	HEOS	HEOS Percentage
1	A.A	70	70	1	100%
2	D.R	67	70	0.95	95.71%
3	S.A	70	70	1	100%
4	L.N	65	70	0.92	92.85%
5	M.D.A	69	70	0.98	98.57%
6	P.R.I	63	70	0.9	90%
7	D.P	65	70	0.92	92.85%
8	R.D.I	69	70	0.98	98.57%
9	M.D.A.K	70	70	1	100%
Average of HEOS *Small Group Trial* stage					96.50%
Categories					Very Practical

Based on the data in the table above, the average percentage in the Small Group Trial stage was 96.50%. These results indicate that the Sustainable Environment-based E-LKPD developed for global warming is highly practical. In the effectiveness test, all students in class X.A were assigned to the experimental class, and those in class X.B to the control class. An N-Gain test was conducted first to determine the product's effectiveness level, followed by a t-test to assess the difference in the average between the experimental and control classes. The data results are shown in Table 7.

Table 7. Average Results of the Experimental Class and Control Class

Class	pre-test Average	post-test Average	N-Gain Score	Category
Class X.A (Experiment)	64.11	83.93	0.65	Medium
Class X.B (Experiment)	50.56	67.17	0.30	Low

Based on Table 7, the N-Gain value obtained in the experimental class was 0.56, which falls into the Medium category, while the N-Gain value in the control class was 0.27, which falls into the Low category. After meeting the requirements, hypothesis testing was carried out. Based on the results of the data normality test above, the data is normally distributed because the Sig value is >0.05. After conducting the normality test, the homogeneity test was continued. The homogeneity test was used to determine whether the respondent groups came from the same population or not. The results of the data homogeneity test indicated that the sample data came from a homogeneous population, as the Sig value (0.159) was> 0.05. Hypothesis testing was carried out using the t-test (Independent sample t-test) with pretest and posttest. The t-coefficient for this independent-samples t-test was calculated in SPSS 25.0. Based on the results of the data analysis above, the calculated t-value is > t-table, so it can be concluded that there is a significant difference between the critical thinking skills of students in the experimental class, whose learning process used SETS-based LKPD, and the control class, whose learning process did not use SETS-based LKPD.

E-LKPD ECO-SETS (Environment and Climate Oriented through Science, Environment, Technology, and Society) is a digital teaching material based on the SETS approach that can be accessed via laptops, computers, and smartphones [28]. This media is designed to support 21st-century learning through phenomena analysis activities, data exploration, collaborative discussions, and simple coding simulations. Integrating climate change and renewable energy materials into coding activities helps students understand the relationship between scientific concepts and real-world events in their environment. This approach aligns with findings [50] that emphasize the importance of interactive conceptual instruction and the use of multiple representations in physics learning to strengthen conceptual understanding and scientific communication skills.

This study uses the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The analysis stage identifies learning needs from both teacher and student perspectives, while the design stage focuses on designing the E-LKPD structure in line with learning outcomes and the SETS approach. The development stage is realized through the creation of an initial prototype and expert validation, while the implementation stage is carried out through limited trials using One-to-One Trial and Small Group Trial to assess the product's practicality. The evaluation stage is carried out continuously at each phase, including improvements to the substance, appearance, language, and effectiveness of coding instructions. The ADDIE model was chosen because it provides a systematic, structured framework for developing technology-based educational products that are oriented to student needs, curriculum, and classroom implementation effectiveness. This is in line with the view [51], which emphasizes that the development of LKPD has been sufficiently tested for validity and practicality to ensure the product's feasibility before being implemented more widely.

In the analysis phase, researchers identified learning needs through teacher interviews and student questionnaires. The analysis showed that students' understanding of climate change remained low, learning remained text-centered, and the media used did not yet integrate digital literacy and simple data analysis. 94% of students agreed on the need for SETS-based LKPD development, and 100% had access to ICT devices, although their experience with simple coding remained limited. These findings laid the groundwork for the need for innovative, interactive, and contextual learning media. After that, researchers formulated learning objectives that referred to the achievements of Phase E of grade 10. The objectives set not only emphasized understanding the physics concept of global warming, but also skills in analyzing data, conducting simulations, and concluding the impact of climate change. Furthermore, students were directed to formulate sustainable lifestyle solutions that could be applied daily. This plan was designed not only to focus on academic aspects, but also to integrate environmental awareness and scientific attitudes in line with the Sustainable Development Goals (SDGs). In the design phase, the initial draft of the ECO-SETS E-LKPD was realized into a digital prototype. Each section is designed following established components, from user instructions and learning outcomes to practical activities. The design accounts for alignment among learning objectives, activity flow, and the Science, Environment, Technology, and Society (SETS) approach [52]. This ensures that the product not only helps students understand the physics concepts of climate change but also fosters awareness of environmental issues in their immediate surroundings[53].

The resulting prototype was then repeatedly reviewed to ensure its quality. Improvements were made to the visual aspects, such as selecting more relevant and clear images, adjusting the font type and size for a neater, more readable display, and arranging components more systematically to facilitate students' following of each

stage of the learning process. The design was created using Canva with a bluish-green hue that symbolizes nature. An illustration of the impact of climate change was added to the center, while a factory emitting thick smoke was chosen as a symbol of emissions in the background. The combination of colors and images made the ECO-SETS E-LKPD more expressive and communicative, while also conveying a strong environmental message. The product was developed in A4 digital format for ease of use in both print and digital formats. In addition to the visual aspects, the review also focused on the coding section, which is the core of the practicum activities. Instructions were checked one by one to ensure the steps aligned with the learning objectives. Researchers tried to run the code snippets directly, correcting incomplete sections and adjusting the syntax to improve understanding for students. This process was carried out as a real-life classroom simulation, ensuring that each line of code executed without issue. The results of the review make coding activities in the E-LKPD ECO-SETS more focused, practical, and aligned with students' needs for understanding the concept of climate change through interactive learning experiences.

During the development stage, the ECO-SETS E-LKPD prototype was validated by experts in materials, design, and language. The assessment covered aspects of material suitability, conceptual accuracy, activity structure, presentation, display, digital accessibility, and relevance to the sustainable environmental context in accordance with the SETS approach. The validation results showed an average of 86.27%, which is categorized as very valid and confirms that the product is worthy of further testing. This finding is consistent with the validity criteria outlined in [26], which state that an average validation result in the range of 86–100% is considered very valid. In addition to these quantitative results, the validators also provided several comments and suggestions that served as constructive input for product improvement. Some of these included improving learning objectives to align with the ABCD rules, adding emission factor information from more valid sources, and technical adjustments such as spacing, layout, and terminology[54]. Other suggestions also emphasized the importance of improving the material structure to be more systematic and adding student instruments and their outlines. All of this input was followed up with revisions to the prototype, improving the quality of the E-LKPD ECO-SETS in terms of content, appearance, and language.

During implementation, the E-LKPD ECO-SETS prototype was tested on a limited basis to assess its practicality. The first trial was conducted through a One-to-One Trial involving three eleventh-grade students representing different cognitive levels: high, medium, and low. They were asked to assess the clarity of the instructions, readability, display navigation, and ease of running the coding simulation. The assessment results showed an average score of 97.14%, which falls within the very practical range. Feedback from students confirmed that the E-LKPD ECO-SETS is easy to understand, the display is not confusing, it can be operated smoothly, and it can foster their interest in learning about climate change issues[55]. After revisions based on input from the One-to-One Trial stage, the next trial was conducted through a Small Group Trial involving nine eleventh-grade students. The assessment results showed an average HEOS of 96.50%, which is also categorized as very practical. Students considered this product easy to understand, with an attractive display, and helpful in connecting physics concepts to real-life environmental issues. The findings show that the E-LKPD ECO-SETS based on coding simulation with the SETS approach is not only valid and practical, but also ready to be used as a physics learning medium that encourages active student involvement while strengthening their understanding of climate change and sustainable environmental issues.

The evaluation stage is carried out continuously in each phase. Evaluation at the analysis stage shows that learning needs have been well identified. Evaluation at the design stage confirms the need for improved navigation and display consistency. Evaluation at the development stage emphasizes the need for validation by more experts and refinement of coding simulations. Evaluation at the implementation stage shows that although E-LKPD is very practical, some students with low abilities require additional assistance in understanding coding syntax. In line with this research, several previous studies also highlight innovations in learning media. [50] shows that developing STEM-based LKS on the topic of work and energy can strengthen students' scientific literacy while improving their critical thinking skills. The findings of [51] indicate that analyzing the scientific literacy profile of high school students on atomic nuclei and radioactivity provides important insights into the need to develop contextual teaching materials. [52] proves the effectiveness of project-based learning in increasing student motivation and engagement in environmental issues. [53] develops an ethnoscience-based science module that has proven effective in developing scientific literacy among junior high school students. [54] confirms that a digital LKPD based on an open-ended approach is valid, interesting, and effective at honing creative thinking skills. Meanwhile, [55] shows that contextual Android E-Handouts are effective in increasing students' interest, motivation, and understanding.

The main difference between this study and previous research lies in the integration of simple coding simulations into the Science, Environment, Technology, and Society (SETS) context, which focuses on sustainable environmental issues. This approach not only presents physics concepts theoretically but also provides investigative, exploratory, and data-driven experiences. Students not only understand the material on climate change and global warming but are also trained to analyze the causes of carbon emissions, predict environmental impacts, and simulate alternative solutions. This integration also strengthens the development of

21st-century skills, such as critical thinking, digital literacy, environmental literacy, problem-solving, and evidence-based decision-making.

The advantage of the ECO-SETS E-LKPD lies in the integration of coding simulations that allow students to explore carbon emissions data, global temperature trends, and environmental impacts through digital practicum activities. Evaluations in the E-LKPD are designed in various formats, including case studies, real-world context-based questions, and decision-making simulations related to climate change. This enables students not only to memorize facts but also to analyze information, evaluate alternative solutions, and formulate relevant actions to address environmental issues. Although the ECO-SETS E-LKPD has many advantages, several limitations should be considered. The complexity of the coding simulations can be challenging for students with low basic skills, so teacher guidance is essential. Furthermore, the product's effectiveness is highly dependent on technological devices and internet access, which can be a barrier in areas with limited infrastructure. Additional support is needed to ensure all students can utilize the E-LKPD optimally.

Considering these advantages and limitations, this study confirms the position of E-LKPD ECO-SETS as an innovative medium worthy of further development. Based on expert validation and student practicality tests, this product is proven to be highly valid and highly practical, and has the potential to serve as a physics learning medium for climate change and renewable energy materials. This product not only improves conceptual understanding, but also fosters environmental awareness and higher-order thinking skills relevant to global challenges. Thus, E-LKPD ECO-SETS is not just a digital product, but a bridge that combines physics learning with environmental awareness, enabling students to learn science while caring for the earth.

4. CONCLUSION

The ECO-SETS E-LKPD, which utilizes simple coding simulations on climate change and renewable energy, was declared highly valid, with an expert validation score of 86.27%. Based on the results of the practicality trials at the One-to-One Trial and Small Group Trial stages, the ECO-SETS E-LKPD achieved average practicality of 97.14% and 96.50%, respectively, both of which are categorized as highly practical. SETS-based LKPD is effective in improving environmental sustainability awareness students in Climate Change Topics for Grade X Senior High School, which is demonstrated by an increase in N-Gain of 0.65 in the experimental class and a significant difference between the experimental class and the control class. Further research is recommended to provide varying levels of difficulty in the evaluation instrument so that students with low basic abilities can still understand the material. Additional guidance and more complex example questions are needed as learning support. Developing an offline version, in the form of an application or interactive PDF, is also important to overcome limitations in technology and internet access, enabling the ECO-SETS E-LKPD to be used more widely across various school conditions.

AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing-Original Draft Preparation, & Visualization, EAP.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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