



## DEVELOPMENT OF INTEGRATED EDUCATION FOR SUSTAINABLE DEVELOPMENT DIGITAL TEACHING MATERIALS ON RENEWABLE ENERGY TO FACILITATE STUDENTS' CRITICAL THINKING ABILITIES

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### Abstract :

This research is motivated by Indonesia's impending energy crisis, where education is seen as one of the solutions to achieve sustainable development in the energy field. Therefore, there is a need for the concept or use of integrated Education for Sustainable Development (ESD) digital teaching materials in the physics subject on the topic of renewable energy. The research aims to determine the process of developing integrated ESD digital teaching materials, to assess the validation results of content and media experts on the teaching materials, and to understand students' responses to the acceptance of the teaching materials. The research method used is Research and Development (R&D) with the Thiagarajan 4-D research model modified with the define, design, and development stages. This study has developed integrated ESD digital teaching materials on renewable energy topics to facilitate students' critical thinking abilities in digital form through the assistance of the fliphtml5 website, which is categorized as very suitable. The expert validation results for content yielded a percentage of 87.6%, which was categorized as very suitable; the expert validation results for media yielded a percentage of 84.6%, which was also categorized as very suitable. Students' responses to accepting the teaching materials were 87.8%, categorized as very suitable.

Keywords: Critical Thinking, Digital Teaching Materials, ESD

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## INTRODUCTION

Indonesia is currently facing an energy crisis, especially in terms of fossil fuels. With the increasing population, likely, energy consumption in Indonesia is also rising, leading to the depletion of fossil fuels (Muhammad et al., 2022), Therefore, there is a need for a transition from fossil fuels to renewable energy sources, as well as efforts to reduce dependence on fossil fuels. The education sector holds a significant responsibility, particularly in terms of curriculum development, and schools play a crucial role in efforts to reduce energy dependence. In 2015, the United Nations introduced the 17 Sustainable Development Goals (SDGs) for 2030, one of which aims to promote clean and affordable

energy use. Understanding and achieving these goals requires commitment and support from various sectors, including the field of education (Fitria & Hamdu, 2021).

Education is recognized as one of the keys to achieving sustainable development (Acevedo-Duque et al., 2023). According to (Amran et al., 2018) education plays a crucial role in creating high-quality human resources. Hence, there is a need for an educational plan that upholds the creation of a generation with outstanding abilities, character, values, religion, mentality, exemplary thinking, ideas, and progress, characterized by intelligent and sincere understanding, and actively contributes to supporting sustainable living.

According to UNESCO (as cited in Azzahra et al., 2022) *education for sustainable development* (ESD) is an effort to provide knowledge, skills, values, and capabilities to communities to effectively and creatively address global issues and create resilient communities. It involves equipping students with scientific knowledge, skills, values, and perspectives to handle information, make informed decisions, and take responsible actions for the ecosystem, sustainable economies, and future generations of society (Purnamasari & Hanifah, 2021). Moreover, according to (Nadiroh & Kasirah, 2017) ESD is a learning activity that develops experiences or demonstrates approaches based on standards and rules to provide quality education and empower community development.

The principle of Education for Sustainable Development (ESD) empowers comprehensive learning (lifelong learning) with creative and easily adaptable learning models that adjust to current environmental conditions and can be implemented through all types of learning programs. The concept is consistently and intentionally carried out to build communities and place great emphasis on the Earth (Matitaputty et al., 2022). ESD is an educational program aimed at educating children and adolescents about the need to limit their dependence on natural and social resources because students' awareness of their current situation impacts their future abilities, hence there is a need for efforts to assist individuals in controlling the development of their emotions (Meda, 2022). In conclusion, Education for Sustainable Development (ESD) is a learning process for students involving an approach that provides knowledge, skills, values, and attitudes in handling information and taking responsible actions toward the environment in facing global challenges.

Students in Indonesia are still classified as having low critical thinking skills, including in the abilities to reason, analyze, and evaluate, as stated by (Natassya et al., 2023) supported by research (Nainggolan et al., 2023) It was found that the critical thinking skills of high school students in eleventh grade are low, especially in the topics of rotational dynamics and equilibrium of rigid bodies. However, these critical thinking skills play a crucial role in supporting sustainable development, including the ability to make decisions and take action. The critical thinking skills of students refer to individual reasoning abilities to survey and handle problems as a whole, where each individual can dissect and analyze existing data, use information, provide solutions with rational reasoning, and take action to address problems (Diva & Purwaningrum, 2023).

The ability to think critically is a skill that students must possess in today's learning because with critical thinking students can think, use mature considerations, and provide appropriate solutions to existing problems (Dhamayanti, 2022). When people engage in critical thinking, they evaluate the results of their thinking process, make the right choices, or distinguish how successfully a problem has been solved (Alsaleh, 2020). The ability to think critically is very important for learners as the future generation, and it is also needed to face global challenges and sustainable development. Without the ability to think critically, individuals are easily deceived by hoax information and prefer information that is not further examined, thus causing new problems later on (Diva & Purwaningrum, 2023). According to Ennis, there are 5 indicators of critical thinking skills, namely elementary clarification, basic support, inference, advanced clarification, and strategy and tactics (Crismasanti & Yuniarta, 2017)

To enhance learning in the 5.0 era, imaginative, interactive, and efficient learning planning is needed, one of which is computerized educational materials in the form of digital learning materials (Mella et al., 2022). Digital teaching materials are teaching materials that can be accessed through Android or Windows devices such as handouts, books, modules, radio, videos or films, and interactive multimedia that can be obtained anywhere and anytime and are interactive (Afwan et al., 2022). The purpose of creating digital teaching materials is to make the learning experience more dynamic, and easier to adapt and change by presenting visuals, and video images, thus conveying learning messages to students (Munawar et al., 2020). (Dewi et al., 2021) their research found that the use of digital teaching

materials in learning activities can enhance students' abilities in creative thinking, problem-solving, motivation in learning, and critical thinking, which can support the achievement of 21st-century learning goals.

There have been several previous studies such as (Khaerunnisa et al., 2019) on the development of physics enrichment books used as teaching materials for renewable energy topics; a study by (Muhammad et al., 2022) developing teaching materials in the form of an electronic module on renewable energy (E-MET): aspects of validity and practicality; (Azzahra et al., 2022) developing an e-module through the Science, Environment, Technology, and Society (SETS) approach on energy topics with the assistance of Lectora Inspire software; a study by (Ewar et al., 2023) developing a simple Geothermal Power Plant (PLTP) model as a physics science learning media for tenth grade renewable energy materials; a study by (Wardiani et al., 2023) developing modules in the form of physics e-modules with the help of the contextual teaching and learning (CTL) model on energy source materials. Of these five studies, none have developed integrated ESD digital teaching materials on renewable energy topics to facilitate critical thinking skills.

(Wijayanti et al., 2021) in their previous study, "Analysis of Physics Teaching Materials Based on the Perspective of Education for Sustainable Development." The research results showed that in the energy sources materials with 5 teaching materials in the twelfth grade in Pemalang Regency, the teaching materials used already presented ESD themes with an average appearance of 21.56%, social-cultural aspects 8.05%, environmental aspects 7.53%, and economic aspects 5.98%. Therefore, this study suggests the development of teaching materials based on ESD for energy sources topics.

Based on the background of the problem, the solution that will be offered is the development of integrated digital teaching materials with the Education for Sustainable Development (ESD) approach on renewable energy topics. These teaching materials are expected to be innovative and creative, facilitating students' critical thinking skills in supporting sustainable development education. Using the ESD approach, these teaching materials will be designed to not only provide an understanding of the concepts of renewable energy but also emphasize the importance of social, cultural, environmental, and economic aspects in the context of sustainable energy utilization. These digital teaching materials will utilize information technology to present information engagingly and interactively, through various media such as text, images, video, and simulations. It is hoped that the development of integrated ESD digital teaching materials on renewable energy topics will positively contribute to improving students' understanding of the importance of sustainable development, and help them develop critical thinking skills in analyzing, evaluating, and finding solutions to energy and environmental-related issues. It is hoped that this solution will be a positive step in supporting sustainable and innovative learning efforts in the field of renewable energy education.

## **RESEARCH METHOD**

This research adopts the Research and Development (R&D) method. Research and Development is defined as the steps or processes to develop a new product and/or improve existing products (Zakariah et al., 2020). This study involves the development of a product in the form of digital teaching materials using an integrated flipbook approach with Education for Sustainable Development (ESD) on renewable energy topics. The research model used is the modified 4-D Thiagarajan 1974 model, which consists of the Define, Design, Develop, and Disseminate stages.

The pilot study of teaching materials was conducted in the second semester of the academic year 2023/2024 at SMAN 1 Wanassalam to determine the students' responses to the acceptance of the teaching materials.

The subjects of this study were 27 students tenth grade of SMA Negeri 1 Wanasalam selected through random sampling. Validation was conducted by 3 experts in the field of content and media towards the teaching materials. The validation was performed to revise the product according to the deficiencies based on feedback and to assess the feasibility of the product.

The research procedure used four stages, such as Define, Design, Develop, and Disseminate.

### ***Define***

This stage identifies current issues through a review of related literature on renewable energy in the real-world context and its relevance to Education for Sustainable Development in the renewable energy curriculum in the independent curriculum. Additionally, an analysis of teaching materials is

conducted to determine the supporting needs for learning activities, such as digital teaching materials and other requirements that will be used in the research.

**Design**

This stage gathers supporting materials for the creation of digital teaching materials. The supporting materials that must be prepared include the content, images, and design layout. Next, research instruments are developed in the form of expert validation sheets for content and media, student response questionnaires, and the design of the initial product.

**Develop**

In this stage, validation is conducted by content and media experts, and the product is revised based on the validators' feedback. After the revision, the teaching materials are tested with students to gather feedback.

**Disseminate**

The dissemination of the developed product was intended to be carried out to students and physics teachers to obtain feedback on the developed product. However, the dissemination of the product was not conducted as the research aimed to produce integrated digital teaching materials with Education for Sustainable Development (ESD) on renewable energy topics to facilitate students' critical thinking skills and to assess the feasibility of the digital teaching materials.

The research instruments consist of experts material instruments, media experts instruments, and questionnaire on students acceptance responses to the teaching materials. The material expert instrument, based on the reference of the National Education Standards Agency (Badan Standar Nasional Pendidikan - BSNP) which is modified, consists of 7 points for the aspects of content suitability, 4 points for the aspect of materia presentation suitability, and 2 points for the aspect of language suitability. The media experts instrument, also based on modified BSNP reference, consists of 2 points for the aspect of teaching material size, 4 points for the aspect of teaching material cover design, 4 points for the aspect of teaching material content design, and 4 points for the aspect language rules. The development trial instrument is used to determine students responses to the acceptance of teaching materials, consists of 5 points for material aspects, 4 points for language aspects, 4 points for interest aspects, and 4 points for graphical aspects. Data collection techniques use validation questionnaires for material and media experts as well as questionnaires on student acceptance responses to teaching materials. The material and media experts consist of 3 individuals, including 1 lecturer and 2 physics teachers, while the respondents consist of 27 sstuent to determine the acceptance of teaching materials.

The data analysis technique used in this study employs quantitative analysis with descriptive statistics to assess the feasibility of these digital teaching materials. According to (Sugiyono, 2013) descriptive statistics is a measurement used to examine information by describing or depicting the information gathered by statistics through sample or population data. This data analysis technique utilizes a rating scale for the validation of expert suitability tests and student acceptance responses to teaching materials. The values of the expert suitability tests and student responses can be seen in Table 1.

Table 1. Criteria Scores of Content Experts, Media Experts, and Student Responses

Response	Score
Excellent	5
Good	4
Average	3
Fair	2
Poor	1

(Purwanto, 2019)

The assessment scale obtained is then processed into percentages using the following equation:

$$\text{Percentage \%} = \frac{\text{Total score obtained}}{\text{Maximum score}} \times 100\%$$

After obtaining the percentage results, then the suitability assessment scale is interpreted based on the suitability test is found in Table 2.

Table 2. Criteria Interpretation of Feasibility of Content, Media, and Student Responses

Validity Criteria	Validity Level
80%-100%	Very Suitable
60%-79%	Suitable
40%-59%	Average
20%-39%	Not Suitable
0%-19%	Very Not Suitable

(Purwanto, 2019)

## RESULTS AND DISCUSSION

### *Define*

Indonesia is currently experiencing an energy crisis due to its dependency on fossil fuels, highlighting the need for a transition to renewable energy or efforts to reduce energy dependence for the population. One of the ways is through education, as it is a key factor in sustainable development. Education integrated with Education for Sustainable Development (ESD) is one solution applied through digital teaching materials. However, the lack of digital teaching materials integrated with ESD is something that needs to be acknowledged and addressed. There have been many impacts of fossil energy on the environment and roles that communities must undertake to manage or minimize fossil energy dependence. Yet, there are still many who are not concerned, both within the community and among students as future sustainable individuals. The second issue is the lack of development in digital teaching materials integrated with ESD, especially for renewable energy topics in the tenth grade of the independent curriculum. Hence, the development of teaching materials integrated with ESD for energy topics aims to facilitate students' critical thinking abilities.

### *Design*

Here is the outline of the teaching materials as seen in Figure 1.

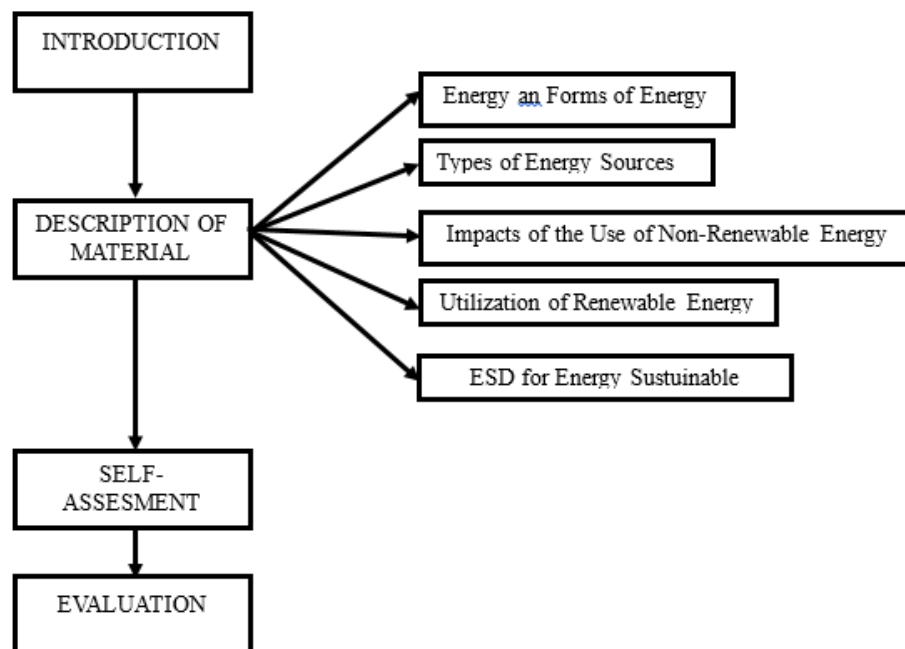


Figure 1. Design of Teaching Materials Outline

The development of content ideas in integrated digital teaching materials with Education for Sustainable Development is adjusted to each subtopic. The outline of the ideas created is explained in Figure 2.

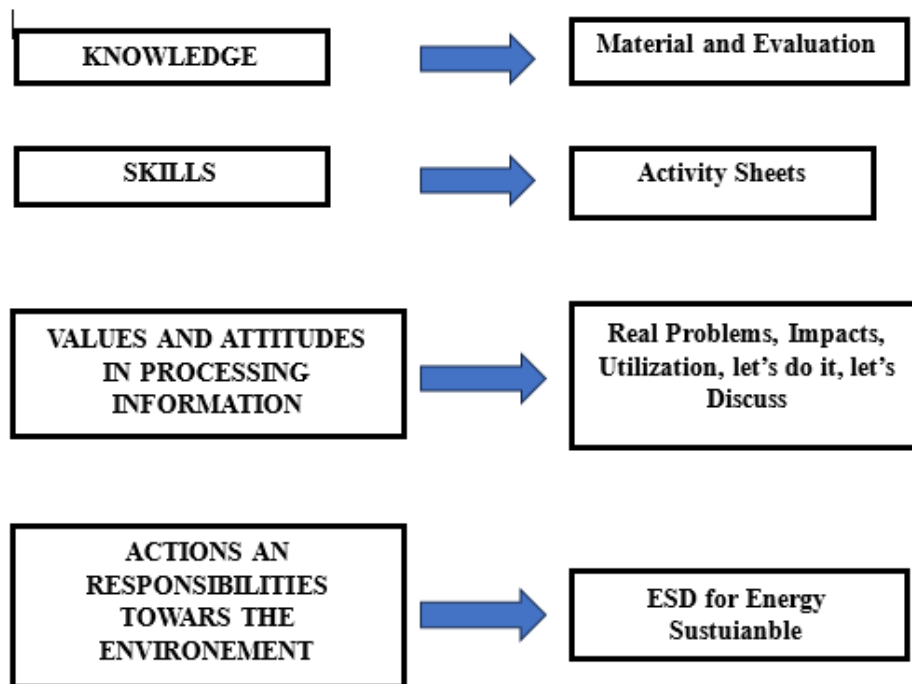


Figure 2. Design Outline of Teaching Materials Content

This teaching material is designed as a digital teaching material connected to the internet and other sources using the website "any fliphtml5." The display of the teaching material can be seen in Figure 3.



Figure 3. Display of Teaching Materials on Fliphtml5 Website

*Develop*

In the development stage, validation of the content and media was conducted for the teaching materials to determine their feasibility. Based on the results from the three validators, the feasibility questionnaire results for the content can be seen in Figure 4, and the feasibility results for the media can be seen in Figure 5.

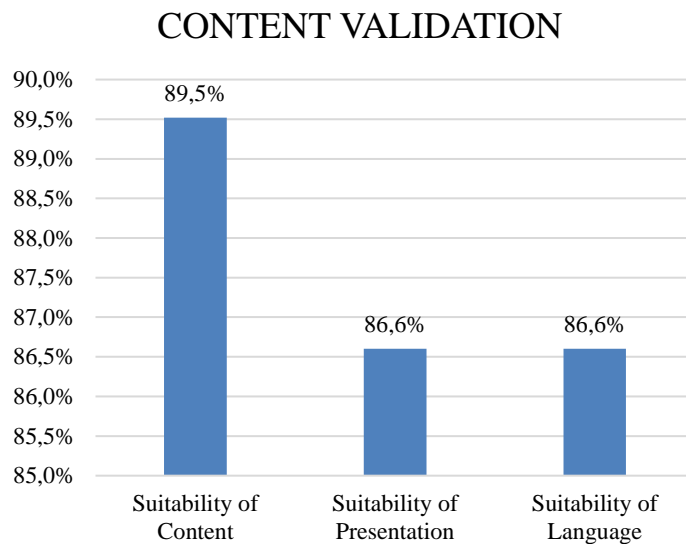


Figure 4. Diagram of Content Validation Results

From the three validators, the aspect of content feasibility obtained a score of 89.5%, categorized as very suitable. Presentation feasibility obtained a score of 86.6%, also categorized as very suitable. Language feasibility obtained a score of 86.6%, also categorized as very suitable.

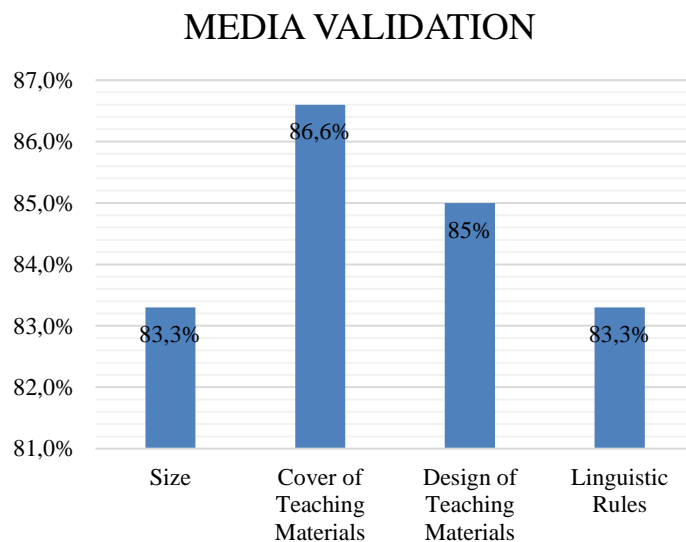


Figure 5. Diagram of Media Validation Results

From the three validators, the validation results for the media aspect are as follows Size of teaching materials 83.3%, categorized as very suitable, Cover design of teaching materials 86.6%, categorized as very suitable, Design of teaching materials 85%, categorized as very suitable, Language rules 83.3%, categorized as very suitable.

Next, the product was revised based on the suggestions and inputs from the validators. Then, the product was tested with the students, and the students responded to a questionnaire to assess their

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acceptance of the teaching materials. This limited test was conducted with 27 students from tenth grade of senior high school 1 Wanasalam. There are 4 aspects assessed Content aspect to assess the ease of understanding the material and its relevance to ESD and critical thinking, the Language aspect to assess the use of easily understood language, Interest aspect to assess the students' interest in the teaching materials and Graphic aspect to assess the fonts, images, colors, and layout arrangement. The results of the limited test with the students regarding the acceptance of the teaching materials can be seen in Figure 6.

### RESULTS OF LIMITED STUDENT TRIALS

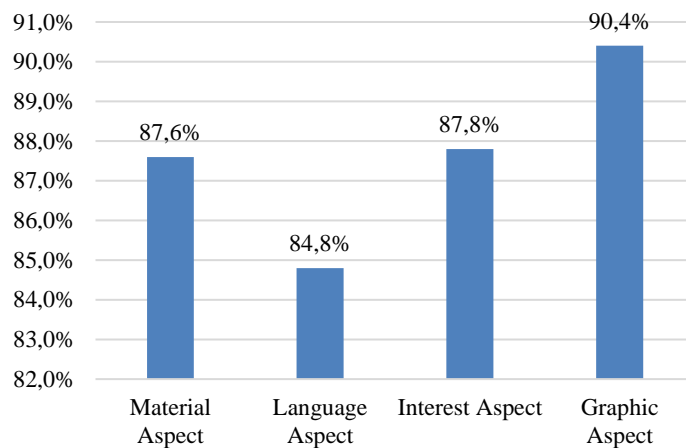


Figure 6. Diagram of Limited Test Results with Students

In terms of material aspect, the result obtained is 87.6% with a category of very suitable, in terms of language aspect, the result obtained is 84.8% with a category of very suitable, in terms of interest aspect, the result obtained is 87.8% with a category of very suitable and in terms of graphic aspect, the result obtained is 90.4% with a category of very suitable.

The suitability of this integrated ESD digital teaching material is based on the results of expert validation of content and media, as well as student responses to the acceptance of teaching materials. In the validation phase, suggestions for improvement were given regarding the media aspect, specifically on the images in the teaching materials. The assessment results of the teaching materials can be seen in Table 3 for content validation and Table 4 for media validation.

Table 3. Average Results of Content Expert Validation

Validator Name	Suitability of Content	Suitability of Presentation	Suitability of Language	Average Validator
Validator 1	88,6%	80%	80%	82,9%
Validator 2	85,7%	90%	80%	85,2%
Validator 3	94,3%	90%	100%	94,8%
Total Average	89,5%	86,7%	86,7%	87,6%

Table 4. Average Results of Media Expert Validation

Validator Name	Size	Cover of Teaching Materials	Design of Teaching Materials	Linguistic Rules	Average Validator
Validator 1	80%	85%	80%	80%	81,3%
Validator 2	80%	80%	80%	75%	78,8%
Validator 3	90%	95%	95%	95%	93,8%
Total Average	83,3%	86,7%	85%	83,3%	84,6%



Based on the assessment from the material validators, an average score of 87.6% was obtained, categorized as very suitable. Then, in the results of the media validation, an average score of 84.6% was obtained, also categorized as very suitable. After the material and media expert validation of the teaching materials, a limited trial was conducted with 27 students to determine the students' acceptance response to the teaching materials. The average score obtained was 87.8%, categorized as very suitable, as shown in Table 5.

Table 5. Average Results of Students Trial Responses to Teaching Materials

Material Aspect	Language Aspect	Interest Aspect	Graphic Aspect	Average
87.6%	84.8%	87.8%	90.4%	87.7%

The overall assessment of the teaching materials is summarized in Table 6.

Table 6. Overall Assessment of Teaching Materials

Assessment	Score (%)	Description
Content Validation	87.6	Very Suitable
Media Validation	84.6	Very Suitable
Student Responses	87.7	Very Suitable
Average	86.6	Very Suitable

Based on the overall assessment results of the teaching materials, an average suitability percentage of 86.6% was obtained, categorized as Very Suitable. Therefore, the integrated ESD digital teaching materials on renewable energy topics to facilitate students' critical thinking skills can be utilized and used in the learning of Physics for Tenth Grade in the Merdeka Curriculum of senior high school.

## CONCLUSION

The development of integrated digital teaching materials for Education for Sustainable Development (ESD) on renewable energy topics to facilitate students' critical thinking skills is conducted through the modified 4D Thiagarajan stages, namely define, design, and develop. The renewable energy content in this digital teaching material is integrated with points of Education for Sustainable Development (ESD). In its presentation, the digital teaching material uses the fliphhtml5 website media.

The suitability of teaching materials is assessed based on expert validation and student responses to the teaching materials. Validation is carried out by 3 expert validators of content and media. The results of the material validation obtained a percentage of 87.6% categorized as very suitable, and the results of the media validation obtained 84.6% categorized as very suitable. There were suggestions from the validators and revisions were made before testing on students. Student responses to the digital teaching materials consist of 4 aspects: material aspect 87.6%, language aspect 84.8%, interest aspect 87.8%, and graphic aspect 90.4%, with an average percentage of 87.7% categorized as very suitable. The overall assessment of the teaching materials resulted in an average suitability percentage of 86.6% categorized as very suitable. Therefore, the integrated ESD digital teaching materials on renewable energy topics to facilitate students' critical thinking skills can be utilized and used in the learning of Physics for Tenth Grade in the Merdeka Curriculum.

There are several recommendations for further research. Firstly, the integrated Education for Sustainable Development (ESD) teaching materials on renewable energy topics to facilitate students' critical thinking skills need further development, both in terms of design and content. Secondly, it is advisable to conduct further research to determine the effectiveness and impact of the teaching materials on students' critical thinking skills regarding renewable energy topics. Additionally, integrated ESD teaching materials would be more beneficial if developed for other physics topics as needed.

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