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Development of Physics E-Modules based on Ethical Dilemma STEAM on Renewable Energy Material

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Abstract
The aim of this development research is to produce a physics e-module based on the Ethical Dilemma STEAM on Renewable Energy material. The model development used in this research is 3D model which is a modification of the Thiagarajan 4D model. This model consists of three development stages, namely Define, Design, and Develop. The research results obtained a learning media product in the form of an electronic module in Canva Website format which consists of three learning activities. This module can be used as an independent learning media that can be used by high school students to enrich their understanding of physics learning on the topic of renewable energy.

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INTRODUCTION

Merdeka Curriculum is the latest curriculum implemented in Indonesia based on the Minister of Education and Research Decree No. 56/M/2022 concerning Guidelines for Curriculum Implementation in the Context of Learning Recovery. This curriculum carries the concept of Merdeka Belajar, which can be understood as freedom in thinking, working, and respecting or responding to changes that occur (Nasution, 2021). This concept aims to create a pleasant learning atmosphere for teachers, students, and parents (Hutabarat et al., 2022). Merdeka Curriculum is present as a curriculum that focuses on essential material and the development of learner competencies at each stage (Ministry of Education, Culture, and Research, 2022). Implementing this curriculum provides ample opportunities for students to actively explore factual issues (Rahayu et al., 2022).

However, the implementation of the Merdeka curriculum in learning faces various challenges. (Angga et al., 2022)

stated that one of the biggest challenges of the Merdeka curriculum is the lack of learning facilities and limited learning resources. (Saputra et al., 2022) Teachers' main problem in implementing the Merdeka curriculum is their low competence and understanding in compiling modules according to the curriculum. (Yusa et al., 2023) In their research on the challenges and opportunities of implementing the Merdeka curriculum, they noted that one of the significant challenges is the lack of resources and infrastructure, such as textbooks, teaching materials, and supporting technology. Modules that align with the latest curriculum are needed, given the lack of adequate and relevant material sources with current content. In their research, Adillah et al. (2023) explained that interactive electronic modules are one of the digital learning media that can support the Merdeka curriculum and are characterized by the characteristics of the Alpha generation in the Society 5.0 era.

The Ethical Dilemma Story Pedagogy (EDSP) approach is rooted in value education and is well-suited for teaching controversial issues. This approach equips students with the ability to engage in evidence-based decision-making, critical thinking, critical reflection, and collaborative problem-solving (Taylor et al., 2019). EDSP adopts an interdisciplinary approach to address social and environmental challenges, with STEM (Science, Technology, Engineering, and Maths) being an integrated learning approach (Rahmawati et al., 2022). In the context of chemistry education, a study (Rahmawati et al., 2022) tested the effectiveness of the Ethical Dilemma-STEAM teaching model, and found that students not only engaged in deep chemistry learning, but also developed reflective social thinking, collaborative decision-making skills, as well as higher environmental awareness to support sustainable development. Similar studies using the Ethical Dilemma-STEAM model, such as the one conducted by Pramashela and Suwono (2023) in virus-related biology subjects, also showed significant results in improving students' creative thinking skills and learning outcomes. Another study (Meiliasari et al., 2024) revealed that the Dilemma-STEAM teaching model effectively engages students in 21st-century

learning, with findings showing that problem-solving activities improved critical and creative thinking skills, collaboration, and communication skills. The research also highlighted the capacity of this model to facilitate a multidisciplinary approach in science learning, providing meaningful learning experiences for students.

A needs analysis conducted with 42 high school students in Jakarta showed that 59.5% of students agreed and 14.3% strongly agreed that e-modules could increase student interest and facilitate the physics learning process with the Merdeka curriculum. 61.9% of students prefer learning using electronic media over printed media. This is supported by the comfort of 52.4% of students in using the internet for learning, while the remaining 47.6% are very familiar with using the internet as a learning tool, so this is not an obstacle. Students want physics learning e-modules that have the following criteria: (1) use clear and easy-to-understand language, display attractive images and the right colour combination, (2) display examples that are by daily life and the characteristics of the local environment, (3) provide practice questions that allow students to measure mastery of the material, (4) equipped with examples and illustrations related to learning materials, (5) use varied media, and (6) the material is presented interactively.

Based on the description above, it is necessary to develop learning media in the form of e-modules on Renewable Energy material based on the principles of the Merdeka Curriculum. The Ethical Dilemma STEAM model is the right model to apply to this e-module because it can facilitate students in understanding factual issues contained in renewable energy material and its application in life.

METHOD

This study uses a research and development (R&D) approach that provides theoretical and practical contributions. Educational product development begins with a needs analysis and literature review, resulting in a product through a series of revisions until the product is ready for use. The media development conducted in this study refers to the 4D development model (Thiagarajan, S., et al., 1974), which was modified into 3D

(Define, Design, Develop), with the following process flow:

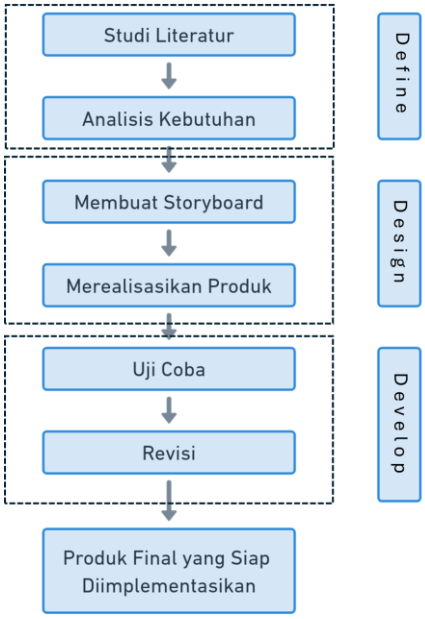

Figure 1. Flowchart of Research and Develop

Define Stage

In this initial stage, the development research model focuses on determining the parameters of the product to be developed. This involves identifying and describing product-related information through literature study and needs analysis. Determining learning objectives and student needs are the main steps in designing products that are relevant to learning needs.

Design Stage

The purpose of this stage is to design the prototype of the product to be developed, which can be started after the learning objectives are set. At this design stage, the e-module storyboard is created and an early version of the product is produced. This design aims to ensure that the product developed is in accordance with the learning objectives that have been set, and can be well received by users.

Develop Stage

At this stage, the initial version of the product is modified into a final version that is ready for use. Feedback is collected through trials, and the product is revised based on the feedback received. A prototype development process of the product is conducted, where the initial version produced at the design stage is modified into a more effective final version. At this stage, the product is trialled and revisions are made to ensure the product meets the learning objectives and can be well received by students.

RESULTS AND DISCUSSION

Results

The present study yielded the production of learning media in the form of Ethical Dilemma STEAM-based E-modules

on Renewable Energy material. This electronic module consists of three learning activities and uses the steps of the Ethical Dilemma STEAM learning model.The following is the application of the syntax of the Ethical Dilemma STEAM learning model stages as e-module instructions.

Table 1. Syntax of Ethical Dilemma STEAM

No	Steps	Instruktion of e-Modul
1	Reflection	Display illustrations and stories of daily life dilemmas related to the material
2	Exploration	Displays questions that provoke e-module user responses
3	Elabora-tion	Presents the concept of learning materials related to the problems in the dilemma story and STEAM project
4	Integrated	Displays STEAM integration instructions in the project as a solution to the dilemma story
5	Transfor-mation	Displays learning evaluation

This e-module is augmented with illustrative materials, including images, videos, graphics, and other media, developed through the utilization of the Canva application. This technological framework facilitates online accessibility for students, thereby ensuring comprehensive engagement with the subject matter.

Figure 2. Display of e-Module

Discussion

Phase E (grade X) of the Independent Curriculum Physics subject encompasses the topic of Renewable Energy, which is of particular significance in the context of its factual nature. Energy is a crucial element for societal well-being and the facilitation of various aspects of life.The incorporation of this material aims to cultivate students' capacity to respond to global issues proactively and assume an active role in problem-solving, preparing them to become leaders in their respective fields.

The e-module under consideration is an ethical dilemma STEAM-based module that integrates ethical dilemma stories suitable for teaching controversial issues and training students to engage in decision-making. It also combines several disciplines in STEAM projects to deal with real-life issues, facilitating students' independent learning of renewable energy material. The

e-module contains examples and stories from everyday life related to the learning materials, thereby helping students understand the learning process. Furthermore, the module incorporates multimedia elements, such as images, videos, graphics, and other media, to enhance student motivation.

CONCLUSION

This development research produces a product in the form of an electronic module (e-module) based on Ethical Dilemma STEAM on Renewable Energy material for Physics subjects at the high school level. The development media used is Canva Website. The resulting e-module is expected to enrich learning media that supports independent learning of students in high school physics subjects on the subject of Renewable Energy. In this study, a 3D development model was used with the Define, Design, and Develop stages. Due to limited research time, this study only implemented three stages of Thiagarajan's 4D development model. Further research is needed to be able to perfect the fourth stage of the 4D model, namely Disseminate.

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