Development of STEM project-based learning student worksheet for Physics learning on renewable energy topic

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Abstract.This research is motivated by the development of education in the 21st-century, which demands students to master the 4C skills (creative thinking, critical thinking, collaboration, and communication), particularly in the field of physics. The nature of physics learning requires active and interactive teaching methods that can be implemented through project-based activities for students. One effective instructional media is the student worksheet designed based on STEM-PjBL (science, technology, engineering, and mathematics project-based learning) principles. This research aims to assess the suitability of STEM-PjBL student worksheets as a learning media, which can serve as a recommendation to assist teachers in teaching renewable energy topics. This study uses the ADDIE model to adopt the Research and Development (R&D) method. This research results in a STEM-PjBL student worksheet as a physics learning media to understand renewable energy topics. The STEM-PjBL student worksheet is expected to assist students in mastering 21st-century skills effectively.

1. Introduction

The development of the 21st-century world is constantly changing and evolving in various fields due to the effects of globalization. In line with these changes, there is a need for social needs and skills to respond to them. One innovative approach that supports meeting the current needs and challenges is education [1]. The competencies of 21st-century learning are known as the 4Cs (creative thinking, critical thinking, collaboration, and communication skills) [2].

One of the primary objectives of contemporary education is to provide students with the necessary skills in creative thinking for problem-solving purposes [3]. Students who are not equipped with 21st-century skills will face uncertainty in tackling global challenges. The creative thinking skills of students have an impact on science learning, particularly in physics. This is supported by research stating that through the process of creative thinking, students will construct their knowledge through learning experiences, thus improving physics learning outcomes [4]. Physics learning is also relevant to the real world and everyday life contexts, and it can utilize technology as a learning tool. Science activities that are connected to students' daily experiences and integrated with technology provide opportunities for students to understand that scientific knowledge is always evolving [5].

An effective strategy for physics learning that can enhance student engagement is using a scientific approach. The scientific approach includes discovery, project, and problem-based learning [6]. Several physics topics such as Measurement, Optics, Electricity and Magnetism, Thermodynamics, and

Renewable Energy can be practiced through hands-on activities. Physics topics are often included in practical experiments because physics concepts tend to involve designing experiments and are relevant to real-life situations [7].

Renewable energy is an important topic to be taught to students as it can spark their interest in responding to environmental issues in their daily lives [8]. Therefore, the renewable energy topic can equip students to analyze, synthesize, and evaluate the importance of using environmentally friendly and sustainable energy in the future for environmental literacy projects [9].

There are several learning media that can overcome constraints in learning activities, such as informal learning experinces [10], project creation [11], and fieldtrips [12]. The mentioned learning media will be successful as long as they run effectively, and students are actively engaged and participative [13]. The appropriate characteristics of media for renewable energy topics are the ability to utilize technology and enhance integrated soft and hard skills [14].

One of the effective learning support media is the student worksheet. Student worksheets are specifically designed and tailored to the learning objectives to facilitate students' understanding of the taught material. Student worksheet needs to consider students' characteristics to become an effective learning media in enhancing students' skills in the taught subject. Therefore, it is necessary for student worksheet to contain various content that enhances students' creativity in learning [15].

The suitable design for the student worksheet in renewable energy topics is using the STEM-PjBL design. STEM, which is for Science, Technology, Engineering, and Mathematics, and it has become a popular term in the education world that refers to integrated interdisciplinary learning with an emphasis on real-world problem-solving [16]. PjBL (Projects Based Learning) is defined as intensive learning that involves and encourages students to solve problems through engaging projects. PjBL also encompasses different activities to reflect the goals and possibilities of project-based learning with students, with clear and realistic objectives [17].

The implementation of STEM-PjBL student worksheet in renewable energy topics is highly relevant because the material can be integrated with STEM concepts and help students apply scientific concepts through renewable energy-based projects. Therefore, in this research, a STEM-PjBL student worksheet for physics learning on renewable energy topics was developed.

2. Method

The Research and Development (R&D) model was chosen for this study because this method is not only used to formulate or test theories but also to develop effective products for use in schools [18]. The research and development in this study follow the ADDIE development model, which consists of Analyze, Design, Developm, Implement, and Evaluate [19].

The selection of the ADDIE model as the development model for the student worksheet is based on several reasons: the development steps are clear, systematic, and directed towards the development process of the student worksheet from start to finish. This model also supports teachers' productivity in producing learning products in the form of student worksheet [20].

2.1. Analyze

In the analysis phase, there are three stages carried out, namely critical incident analysis, resource analysis, and project analysis. In the critical incident analysis stage, the aim is to analyze the specifications of the subject, learning outcomes, and learning objectives in the context of renewable energy. Then, in the resource analysis stage, the objective is to analyze the learning resources related to renewable energy. Lastly, in the project analysis stage, the aim is to analyze the design of an engaging renewable energy project for the students.

2.2. Design

The design phase aims to verify the desired performance through appropriate testing methods. In this phase, a supporting learning tool or media will be designed to address the identified problems in the

research, particularly in the school learning activities. In this stage, a student worksheet for the renewable energy topic will be designed.

2.3. Develop

The development phase aims to produce and validate the selected learning resources or media. Once completed in the development phase, the learning media needs to be identified for use in the learning activities. The outcome of the development phase is the creation of learning tools or media that are implemented in the learning activities. In this phase, the developed student worksheet will be aligned with the competencies and assessed and validated through questionnaires provided to media experts and subject matter experts.

2.4. Implement

The implementation phase aims to prepare the learning media that has been developed in the previous phase for testing with students and teachers. This phase involves the actual use of the learning media in the classroom. It serves as a conclusion and transition phase between the development and evaluation phases, where the effectiveness and usability of the learning media are observed and assessed. After going through the development phase, in the implementation phase, strategies are needed to optimize the use of the designed student worksheet as a learning media for students and teachers.

2.5. Evaluate

The evaluation phase consists of activities to assess the suitability of the developed media. Evaluation of learning outcomes is conducted in this phase using the developed student worksheet. The evaluation includes assessing students' learning outcomes, measuring the effectiveness of the student worksheet, and evaluating the effectiveness of teachers in implementing the student worksheet.

After conducting validation tests and field tests, the next step is to analyze the data by calculating the percentage scores. This research focuses on the development of STEM-PjBL student worksheets on renewable energy. Therefore, the data is analyzed using a descriptive percentage system. The data obtained from the validation tests by subject matter experts, media experts, as well as field tests conducted with teachers and students, are analyzed by calculating perception or opinion scales using a Likert scale ranging from 1 to 4 [21].

Table 1. The Likert Scale

Score	Interpretation
4	Highly Compatible
3	Compatible
2	Fairly Compatible
1	Not Compatible

Next, the validation results of the research are calculated using equation (1).

$$V = \frac{\sum X}{N} \times 100\%$$

Explanation:

V : Value

$\sum X$: Total Point

N : Maximum Point

The obtained percentage scores are then interpreted into four interval classes to determine whether the product is considered suitable as a learning support media for renewable energy material.

Table 2. The Category of Validity Result

Score	Interpretation
81% < score ≤ 100%	Highly Compatible
63% < score ≤ 81%	Compatible
44% < score ≤ 63%	Fairly Compatible
score ≤ 44	Not Compatible

3. Result and Discussion

The product of this research is a STEM-PjBL student worksheet for renewable energy topic. The student worksheet based on STEM-PjBL is divided into two project activities. The first project is creating a mini solar car, and the second project is creating a solar wind project

The STEM-PjBL learning model aims to engage students more in authentic problems. Generally, STEM activities heavily involve PjBL and are based on engineering or technological design challenges. Another argument is that PjBL can be more effective in developing critical thinking skills in STEM and fostering creative, innovative, and collaborative problem-solving between students and teachers [22].

The components included in the STEM-PjBL student worksheet are as follows cover, description of the student worksheet, instruction, learning outcomes, learning objectives, the main content section, project activity 1, project activity 2, conclusion, assesment, and list of references. The following is the design of a STEM-PjBL student worksheet on renewable energy topics.

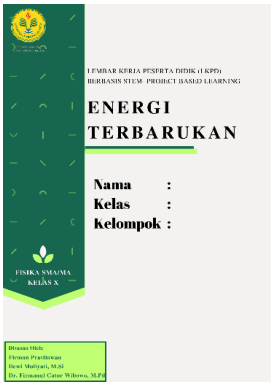

Figure 1. The Cover

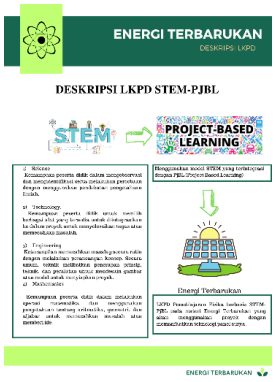

Figure 2. Description of student worksheet

Figure 3. Instruction

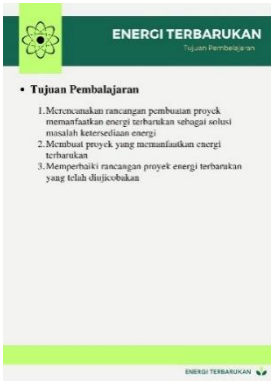

Figure 4. The learning objectives

Figure 5. The main content

Figure 6. The project activity

The development phase involves the assessment by several experts and limited-scale trials. In this study, the student worksheet was tested to verify the criteria for content and media presentation. Validation tests were conducted to demonstrate the validity of the created student worksheet and obtain feedback and suggestions for improvement. The results of the media validation are presented in Table 3 and Table 4.

Table 3. The Media Validation Assessment Results

The Component Criteria	Average
Function	
The student worksheet engagingly presents learning materials.	3.00
The student worksheet can help students understand and apply concepts of renewable energy.	3.00
Authenticity	
The student worksheet is relevant and reflects the real world in the context of renewable energy.	4.00
The student worksheet provides real-life experiences or simulations in creating renewable energy technologies	4.00
Visual Appearance	
The typography used facilitates understanding, readability, and attractiveness.	3.00
Appropriate use and combination of colors	4.00
Appropriate use of font combinations	3.00
Average Point	3.43

Table 4. The Material Validation Assessment Results

The Component Criteria	Average
Relevance of content	
Relevance of the content to Learning Outcomes (LO)	3.00
Accuracy of the content	3.00
Supporting materials for content delivery	4.00
Linguistic aspects	
Suitability for the student's comprehension level	3.00
The simplicity of sentence structure used	4.00
Average Point	3.40

The average validation scores of the STEM-PjBL student worksheets on renewable energy material are as follows: media validation score is 3.43, and the material validation score is 3.40. The obtained validity reaches 85.4%, which characterizes it as highly compatible. However, practitioners have provided reviews that can be used as a basis for improvement to make the student worksheet a more suitable learning media during the school implementation phase. The assessment of the STEM-PjBL student worksheets on renewable energy material, conducted on a limited scale in this research, is beneficial for determining the level of media usability.

Implementing the STEM-PjBL model in physics education is expected to enhance students' creative thinking skills. Therefore, the author created this instructional media as an effort to help students improve their creative thinking skills.

Student worksheets were chosen as the instructional media because they are a popular and effective type of learning media in assisting students in independent learning. A well-designed student worksheet can help students better understand the learning objectives and STEM-PjBL concepts and enhance students' creative thinking skills through active and participatory learning methods.

4. Conclusion

This research results show that the STEM-PjBL student worksheet is an appropriate instructional media for understanding renewable energy materials. The STEM-PjBL student worksheet is expected to assist students in effectively comprehending the concepts through project-based activities that utilize solar panel technology. This student worksheet aims to facilitate students in understanding the material and enhance their thinking skills, and increase their motivation to learn.

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