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Development of Volta Drive Connect Media to Strengthen Energy Literacy of Elementary School Students

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Abstract: Science learning in elementary school often faces obstacles in conveying abstract concepts such as energy transformation, so it requires concrete learning media. This research aims to develop Volta Drive Connect, a project-based science teaching kit in the form of a solar-powered toy car, and to test its feasibility, practicality, and effectiveness in improving students' energy literacy. Using the Research and Development (R&D) method with the ADDIE model, this research was conducted with grade IV students at SD Nasional Kakuka and SD Negeri Simbarejo. The results of expert validation show that the design of the materials and media is highly feasible. In the effectiveness test, Volta Drive Connect proved to be significant in improving students' energy literacy. This was demonstrated by the paired-samples t-test ($p<0.05$), indicating an increase in the average score from 66.8 to 78.3. The use of this media not only motivates students and increases environmental awareness but is also aligned with the achievement of the Sustainable Development Goals (SDGs). In practice, this media provides an alternative innovative solution for teachers in facilitating student-centered basic science learning. In addition, the implementation of Volta Drive Connect encourages students to actively participate in learning through hands-on experimentation and collaborative activities. Students are involved in assembling and testing solar-powered toy cars, allowing them to understand the concept of energy transformation through real-world experiences. It also supports the development of science process skills, such as observation, problem-solving, and teamwork, which are important competencies in basic science education. Therefore, Volta Drive Connect not only contributes to improving students' conceptual understanding of energy but also to fostering positive attitudes towards renewable energy and sustainable environmental practices.

Keywords: ADDIE; Energy Literacy; Energy Transformation; Learning Media; Renewable Energy.

Introduction

The low level of science literacy of elementary school students in Indonesia is still a challenge, especially in the provision of innovative learning media that is contextual and in accordance with the cognitive development stage of students [1]. Basic science education is an essential skill for students to understand scientific phenomena and apply them in daily life [2]. Basic science education also encourages critical thinking, problem analysis, and the application of scientific methods [3]. However, Natural Science (IPA) learning on energy materials still tends to focus on the delivery of theory and has not optimally utilized interactive learning media. The one-way learning model is not optimal enough to improve students' understanding of abstract energy concepts [4]. In reality, elementary school students tend to have a kinesthetic learning style, which requires activity-based, practical learning media [5]. The limited facilities and learning media that are not in accordance with current technological developments result in the level of energy understanding in elementary school students being relatively low [6].

On the other hand, energy education in Indonesia has not yet reached a comprehensive understanding among the public. Efforts to improve energy literacy and renewable energy are very important and in line with the achievement of the Sustainable Development Goals (SDGs) [7], especially Clean and Affordable Energy, Responsible Consumption and Production, and Climate Change Management. Considering that Indonesia has a huge potential for solar energy, with the intensity of the surrounding sunlight 4,8 kWh/m^2 for the day [8], the introduction of alternative energy sources from an early age through schools is a strategic step. In this case, teachers have an important role in shaping students' understanding, attitudes, and responsible behaviors regarding energy consumption [9]. Based on the theory of constructivism, if students have the opportunity to interact with real objects and gain direct experience from the learning process, then the concepts of technology and energy can be understood more easily [10]. Students need to be directly involved in observation, experimentation, and problem-solving activities, as teaching kits that enable hands-on learning experiences are proven to enhance students' conceptual understanding and practical skills [11].

Although the use of solar panels in education is growing, several studies show that solar cell technology has increased mastery of the concept of energy transformation and the ability to think scientifically [12]. Primary schools still face obstacles in providing teaching aids that combine the concept of renewable energy with real life in a structured manner. This gap creates an urgent need to develop more

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innovative and contextual learning solutions. As a novelty, researchers developed the Volta Drive Connect interactive teaching kit that integrates hands-on activities with project-based worksheets. Not just a teaching aid, this teaching kit encourages experiment-based learning that develops critical thinking and collaboration skills [13], for example, through testing a solar-powered toy car that trains students to analyze the cause-and-effect relationship on the energy conversion process [14]. The development of Volta Drive Connect media was undertaken to test its effectiveness as an innovative medium for improving students' energy literacy. Through systematic practical activities, students are invited to explore the concept of energy and relate it to everyday experiences, as a real effort to answer the challenges of learning energy literacy in Indonesia.

Research Methods

Jenis dan Desain Penelitian

This research uses the Research and Development (R&D) method with the ADDIE (Analyze, Design, Development, Implementation, Evaluation) model, which was chosen because of its systematic and flexible nature in sustainable product development [15]. The development flow of this ADDIE model was adapted from Branch [16].

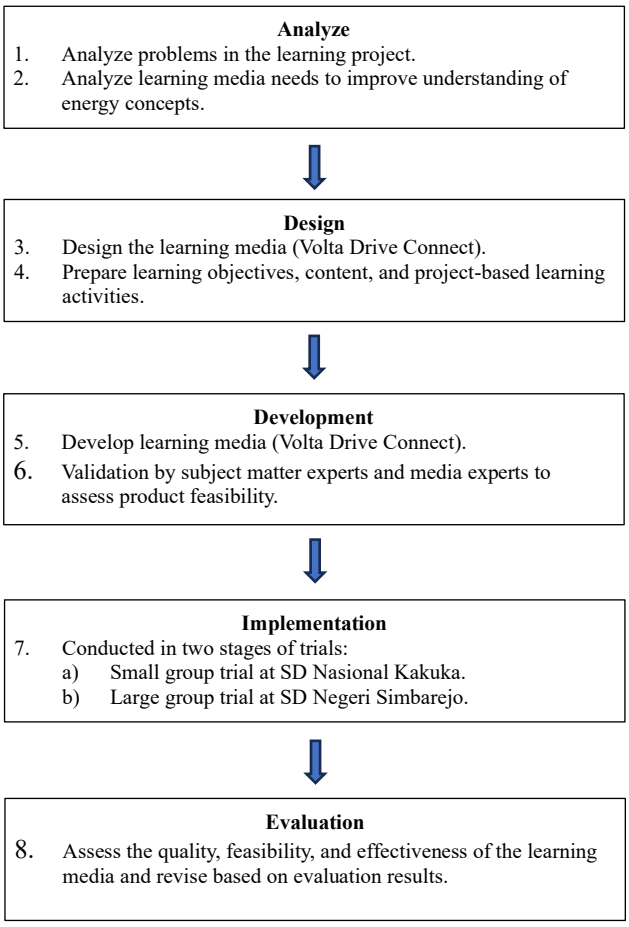

Figure 1. Flowchart ADDIE

The Analyze stage is carried out to identify the needs and problems of energy learning in students. The Design stage focuses on designing the Volta Drive Connect teaching kit, learning objectives, and learner worksheets. The Development stage includes product creation, validation by material and media experts, and media revision. The Implementation stage was carried out through small-scale trials at Kakuka National Elementary School and large-scale trials at Simbarejo State Elementary School. The Evaluation Stage aims to assess the quality and effectiveness of the developed media.

Product effectiveness evaluation was carried out through a Quasi-Experimental approach with a pre-test, post-test control group design. To optimize the measurement of energy literacy improvement at the implementation stage, the focus of the analysis was intensively directed to the observation of the results of the experimental group before and after using Volta Drive Connect. As a measure of compliance with research ethics standards, the entire series of implementations was carried out after obtaining official permission from SD Nasional Kakuka and SD Negeri Simbarejo, as well as approval for participation from the students involved.

Research Subject

The research subjects are grade IV students who have studied energy materials in science, making them relevant to the purpose of measuring energy literacy. The total number of subjects was 39 students, who were divided into two trial stages. Small-scale tests with 14 students of Kakuka National Elementary School, and large-scale tests with 25 students at Simbarejo State Elementary School.

Data Collection Methods

Data collection is adjusted to the development stages, namely: observation at the Analyze stage to identify learning problems and needs, questionnaires to assess the feasibility of products by experts and media practicality by teachers and students, tests (pre-test and post-test) to measure energy literacy, and documentation as supporting data for research implementation. To ensure the validity and reliability of the data and results, the test instruments and rubrics for assessing energy literacy underwent validity and reliability tests before being distributed to the research subjects, ensuring that the measuring tools were consistent.

Data Analysis Techniques

This study uses a quantitative approach to objectively measure changes in student learning outcomes before and after the use of the developed media [17]. The analysis process goes through two main stages. First, descriptive statistics are used to provide an overview of the overall research results [18]. This analysis includes calculating the mean, percentage, and improvement in learning outcome scores using the N-Gain formula, which is proportional to the student's initial ability. The interpretation of the N-Gain value is based on the Hake categories: high ($g > 0.7$), medium ($0.3 \leq g \leq 0.7$), and low ($g < 0.3$) [19]. Second, inferential statistics are used to test research hypotheses [20]. Before testing, a prerequisite test was performed, which included a Shapiro-Wilk normality test to ensure that the distribution of results met the requirements of parametric statistical testing [21], and homogeneity tests to ensure that

data between groups had equal diversity [22]. After the data were collected, a paired-samples t-test was conducted at the 5% significance level (0.05) to determine whether there was a significant difference in students' energy literacy scores before and after using Volta Drive Connect media.

Results and Discussion

Volta Drive Connect Media Description

This research resulted in a product, Volta Drive Connect, a project-based science teaching kit designed to resemble a solar-powered toy car. This media is equipped with assembly components such as mini solar panels, dynamos, serrated wheels, connector cables, and used bottles for the car body. To facilitate students' cognitive development, the assembly process is divided into progressively more difficult levels. Level 1 for basic component introduction, level 2 for drive system assembly challenges, and level 3 for complete assembly that demands independent troubleshooting.

Figure 2. Volta Drive Connect Level 1 Design and Components

Figure 3. Volta Drive Connect Level 2 Design and Components

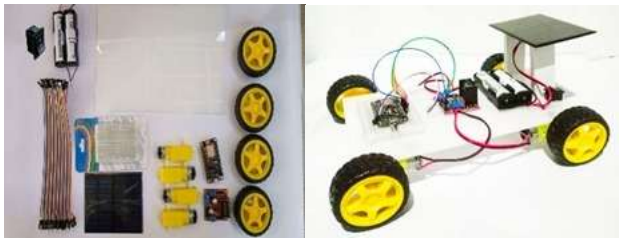

Figure 4. Volta Drive Connect Level 3 Design and Components

Media Validation and Practicality Results

Volta Drive Connect media has been validated by material and media experts before implementation. The material validation results obtained a score of 13 out of 16 (very feasible category), while the media validation results obtained a score of 22 out of 24 (very feasible category). In more detail, the media validation results are presented in Table 1.

Table 1. Results of Material and Media Validation

	Aspect	Score Maks	Score	Category
Material Validation	Material Accuracy	3	3	Highly Worth It
	Readability	3	2	Good
	Worksheet Conformity	3	3	Highly Worth It
	Concept Accuracy	3	3	Highly Worth It
	According to the student's character	4	2	Quite Decent
	Quantity	16	13	Highly Worth It
Media Validation	Security	3	2	Good
	Ease of Use	3	3	Highly Worth It
	Attraction	3	3	Highly Worth It
	Quality of Procedure	3	3	Highly Worth It
	Energy Exploration	3	3	Highly Worth It
	Energy Conversion Tools & Materials	3	3	Highly Worth It
	Energy Conservation Experiments	3	3	Highly Worth It
	Completeness Guidelines & worksheet	3	2	Good
	Quantity	24	22	Highly Worth It

Based on Table 1, the percentage of material feasibility reached 81.25% (very feasible category) and media feasibility reached 91.67% (very feasible category). This indicates that this media is in accordance with the characteristics of the students and is able to accurately visualize the concept of energy transformation. Effective learning media must be able to bridge abstract concepts into more concrete ones so that they are easy for students to understand.

The implementation stage was carried out consistently by involving a total of 39 grade IV students, divided into two stages. The first phase was a small-scale trial with 14 students at Kakuka National Elementary School, aimed at evaluating initial practicality and refining the assembly guidelines. The results of the practicality test at this stage get a teacher score of 20 and a student score of 34 (very good category). Based on these inputs, minor revisions were made to the connectors and a glossary was added to the Student Worksheet (LKPD) to ensure the level of media complexity was in accordance with the student's initial ability.

The Effectiveness of Media on Student Energy Literacy

The second stage was a large-scale effectiveness test involving 25 students at Simbarejo State Elementary School. The effectiveness of media is measured by increases in energy literacy, which includes several indicators: concept understanding (cognitive), science process skills (psychomotor), and energy awareness (affective). The average overall energy literacy pre-test score was 66.8%, increasing to 78.3% on the post-test, a relative increase of 17.2%. To provide a more comprehensive picture, the analysis of improvements in learning outcomes is elaborated for each energy literacy indicator using the N-Gain test, as presented in Table 2.

Table 2. Improving Energy Literacy Based on Indicators (N-Gain)

Energy Literacy Indicators	Average Pre-test	Average Post-test	N-Gain	Category
Understanding the concept of energy transformation	65.4%	80.6%	0.44	Medium
Science process skills (experiments)	62.5%	74.8%	0.33	Medium
Energy-efficient awareness and behavior	72.5%	79.5%	0.25	Low
Total average Overall	66.8%	78.3%	0.35	Medium

Based on Table 2, the use of Volta Drive Connect improves all energy literacy indicators. The highest increase occurred in the indicator of understanding the concept of energy transformation, while the lowest increase was in the indicator of energy-saving awareness and behavior. Through the assembly of solar panel teaching kits, students are directly involved in the process of exploring concepts, so that learning is not only informative, but also constructive [23]. In addition, assembly activities contribute to the development of science process skills, such as the ability to observe and assemble components [24]. Inferential statistical evidence from a paired-samples t-test corroborated this finding, with a significance value of 0.000 ($p<0.05$). This confirms a statistically significant difference in students' energy literacy before and after the implementation of Volta Drive Connect.

Significant improvement of energy literacy is based on structured theoretical mechanisms. The success of Volta Drive Connect proves that project media not only serves as a visual aid but also bridges the gap between abstract theory and meaningful, hands-on learning tools. Theoretically, science literacy cannot be optimally internalized only through physical interaction with real objects. This medium accommodates cognitive needs by transforming invisible concepts, such as the process of transforming light energy into electrical energy, then into kinetic energy, into a mechanical reality that can be felt, assembled, and manipulated directly by students.

During observation, the dynamics of learning changed drastically. Student involvement is very active in completing level 3 challenges on the product. Although some students encounter technical challenges in assembling gears and dynamos, these challenges also encourage collaboration during the learning process. Technical difficulties prevent students from becoming passive participants and encourage them to discuss, evaluate mistakes, and find problem-solving solutions together in groups. This reflective process is crucial in developing the metacognitive aspects of students, which are important indicators in 21st-century competencies [25].

The energy-saving awareness and behavior indicator obtained an N-Gain value of 0.25 in the low category, but still showed an increase after the use of media. Direct engagement facilitates students to see the real-world nature of the conversion of solar energy into mechanical motion energy, effectively instilling an understanding of the importance of utilizing renewable energy sources in real life [26]. This real-world experience aligns with the goals of renewable energy education (SDGs) to produce a generation with an analytical and environmentally sound mindset. Overall, the role of teachers is that of facilitators who create an exploratory environment, which demonstrates that the combination of pedagogic competence and the innovative media of Volta Drive Connect has succeeded in achieving the science learning target at the primary school level. The results of the achievement of the overall research target are summarized in Table 3.

Table 3. Evaluation of the Achievement of Research Targets

No.	Indicator	Target	Achievements	Status
1	Kit Practicality	Good	Excellent	Achieved
2	Energy Literacy	15%	17,2%	Achieved
3	Renewable Energy Intention	60% Students	68% Students	Achieved

Conclusion

The results of the study show that Volta Drive Connect is highly feasible, practical, and effective for improving the energy literacy of elementary school students. Through a project-based approach, this media has succeeded in condensing abstract energy concepts into meaningful, applicable, hands-on learning experiences. The use of this media significantly strengthens students' energy literacy holistically, encompassing cognitive (concept comprehension), psychomotor (science process skills), affective (environmental awareness), and metacognitive (problem-solving skills) domains. This success brings practical implications for the education ecosystem. For teachers, this media is an effective instrument to shift conventional theoretical learning towards student-centered interactive learning. For curriculum developers and policymakers, these findings underscore the urgency of integrating renewable energy education and science engineering into the basic curriculum as a strategic step to support the achievement of the Sustainable Development Goals (SDGs). As a follow-up to the technical obstacles identified, further media development is suggested to improve the mechanical design, especially the dynamo hooks and gear wheels, to make them easier for students to

assemble without r educing the element of learning challenge. Subsequent research is also suggested involving a more diverse subject to expand the generalization of the findings. In addition, long-term research is needed to examine the retention of students' conceptual understanding as well as the impact of media on the formation of energy-efficient behaviors in daily life.

Author's Contribution

F.M. Afina: serves as the main researcher, preparing the research design, developing the Volta Drive Connect media, conducting data collection, and performing analysis and writing the manuscript. A. Khoiri: contributed to strengthening theoretical concepts and to the critical evaluation of the article's content. V.I.A. Faisal: contributed to the review and refinement of the manuscript. All authors contribute significantly and agree to the publication of this article.

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