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Solar-powered electric car: validity and effectivity of prop in energy conversion learning

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ABSTRACT

The research aimed to describe the development of solar electric cars as a prop in energy conversion learning using the analyze, design, develop, implement, and evaluate (ADDIE) model and to ascertain the effectiveness of an electric car as a prop in energy conversion learning. Utilization of prop in the learning process is one way to support the development of knowledge, skills, and basic needs for delivering material, concepts, and physics information. This research is a descriptive study involving media and pedagogical experts and 40 students of the university in Tasikmalaya. Data collection techniques were carried out through the study of literature, expert validation, and student perception questionnaires. Expert validation and student perception were obtained by using a Likert scale. The expert judgment results were processed using the V value equation developed by Aiken. The results showed a value of 1, meeting the minimum validation requirements. The students also had positive responses to a prop. They have new experience learning in energy conversion and have good media to help their comprehension. It has a significant impact on helping students to achieve their learning goals.

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1. INTRODUCTION

Learning activities involve interaction between students and various parties involved, such as educators and learning resources in the learning environment [1]. The maximum achievement of learning objectives can indicate practical learning activities and cannot be separated from how the learning process is carried out inside and outside the classroom. The goal of physics learning activities is to facilitate students' understanding of the concepts and principles of physics [2]. It is expected to be the basis for developing knowledge, skills, and self-confidence. It can utilize all aspects obtained during learning to be implemented in daily life.

Physics learning focuses on learning objectives that lead to the embodiment of the physics concept. It is oriented toward finding truth through a systematic and holistic thought process without ignoring norms related to humanity [3]. With technological advances that have developed significantly, physics learning activities benefit from facilitating learning activities through technology-based learning media, innovation, and creativity [4]. Effective physics learning cannot be separated from the media. Effective learning media really has a significant impact on learning activities. Media, which includes learning aids in teaching, also means the carrier of messages or learning resource information to recipients of learning messages. As transmitters and distributors of messages, learning media can represent teachers in presenting learning material to students [5]. The use of learning media in the teaching and learning process can generate new desires and interests, create motivation, stimulate teaching activities, and even have a psychological effect on students [6]. Rizal *et al.* [7] states that the benefits of learning media include i) making the learning process more interesting so that it can raise students' learning motivation, ii) clarifying learning material so that students can easily understand the material, iii) making the learning process more varied, and iv) involving students in carrying out a number of activities during learning, including observing, performing, demonstrating. Learning media that is used effectively in various forms can help reduce visual perception difficulties experienced by students [8].

Energy conservation is one of the courses in the physics education department at Universitas Siliwangi. This course supports the achievement of competency in attitudes and analysis in the field of energy utilization and management, especially in the conversion and conservation sectors. With a good understanding of the use and management of energy, it is hoped that we can meet human needs in the present without reducing the ability to fulfill energy in the future (energy sustainability) and still pay attention to ecological aspects to achieve balance. To be able to hold this lecture, students require independent experimental activities or interactive demonstrations to present information related to energy conversion. The physics education laboratory facility currently consists of 1 basic physics laboratory room with a practicum capacity of 20 people. It equips with practicum tools in the form of 4 units of basic physics practicum of Integrated Instrument Components (IIC) for each central practicum theme (mechanics, electricity and magnetism, optics, and waves and thermodynamics). The current practicum IICs cannot show contextual energy conversion with renewable energy sources. Implementing laboratory activities still faces various obstacles, such as incomplete tool sets, unavailable tools and materials, inadequate activity instructions, damaged laboratory equipment [9]. The limitations of the available tools to support physics learning will have an unfavorable impact on learning outcomes [10].

Considering the need for several instruments to show the phenomenon of energy conversion that is more contextual, it is necessary to have an innovative learning medium in the form of an energy conversion demonstration instrument. The props are one of the learning media, which is a form of depicting the working mechanism of an object [11]. A prop is a tool used to educate and deliver material, either objects or behavior, making it easier for students to understand the material [12]. The props contain the characteristics and forms of the teaching materials used to demonstrate the material in events and activities so that the material can be more easily understood [13].

Using props in the learning process is one way to support the development of knowledge, skills, and basic needs for delivering material, concepts, and physics information [14]. It can be used as learning media and channel messages that stimulate students' thoughts, feelings, and willingness to encourage their learning process [15]. Educational visual props are arranged based on the principle that the knowledge that exists in every human being is received or captured through the five senses. The props have a function to demonstrate events, activities, phenomena, or the working mechanism of an object. The existence of props is intended to mobilize as many senses as possible to an object to facilitate perception [16]. Seeing the potential of teaching instruments that can support the effectiveness of learning activities and renewable energy issues, the research developed a solar electric car, which will be used as a teaching instrument in energy conversion learning.

One of the issues often present in energy conservation is the need for renewable energy to overcome the increasing energy needs and replace the diminishing fossil energy sources [17]. In a press release, the ministry of energy and mineral resources stated that in a global culture, the world would continue to move towards utilizing energy sources by reducing fossil energy and switching to environmentally friendly energy. The demand for green products produced by the green industry is increasing and even becomes a necessity if you do not want your products to be subject to a carbon border tax at the global level [18]. Green products were also reinforced by the President of the Republic of Indonesia in his mandate, prioritizing himself in initiating energy transformation towards new and renewable energy. A green economy, green technology, and green products must be strengthened so that we can compete in the global market [19], [20].

Learning props on energy conservation and renewable energy requires the development of teaching props that adapt to these two needs. Several researchers have developed teaching props used in learning energy conversion. Pauji *et al.* [21] has developed an energy conversion tool for high school students. The toolset converts motion energy into electrical energy using a dynamo. Jufri [22] developed a simple energy conversion tool that can only show the change in the form of motion energy into electrical energy, which is focused on elementary science learning. Rohman *et al.* [5] has developed a demonstration tool for converting energy from various forms of energy into electrical energy. These props are large and complex to mobilize. From all of this research, the props that have been developed do not show a display of magnitude energy before and after conversion, so students do not find out how efficient the props are. Apart from that, students only use tools indoors.

Considering the shortcomings of existing energy conversion props, it is necessary to develop a learning prop that can provide memorable learning experiences to students and also consider the use of renewable energy. So, a solar electric car teaching aid was designed to provide students with a meaningful learning experience by driving an electric car and also displaying converted energy data. Therefore, this research has two main objectives: to explain the development of a solar electric car as a prop in energy conservation learning and to ascertain the effectiveness of an electric vehicle as a prop in energy conservation learning.

2. METHOD

This research was conducted using research and development methods, which focused on developing solar-powered electric cars as teaching aids for energy conversion. The research design used the analysis, design, development, implementation, and evaluation (ADDIE) development model [23]. This model is the most widely used framework for developing instructional learning [24]. This research was conducted at a state university in Tasikmalaya, West Java, Indonesia. Two media experts were involved in validating the teaching aids, and 20 students tested the practicality of the prop. These are the first-semester students with a composition of 15 women and five men. The instruments used in this study consisted of an interview form, a media and material expert validation form, and a Likert scale student perception form.

2.1. Analysis

The analysis is the phase that identifies the learner's needs on learning goals [25]. There are many detective works, background research, and information gatherings. This phase should be carefully taken through observation, interviews, focus groups, or studying written materials such as syllabi, articles, teaching materials, and credible online information [26]. In the analysis phase, several activities are carried out to analyze various research needs based on information obtained through field study activities related to the need for teaching aids. Field and literature studies are the main activities of this analysis phase [27]. Field studies in this study were carried out with various activities, including i) observing energy conservation learning activities, ii) interviews with lecturers to investigate various problems in energy conservation learning as material for recommendations and solutions for the presence of instruments, and iii) interviews with students who have participated in learning energy conservation to obtain in-depth information related to student responses to the lectures that have been held as well as to collect suggestions for improvement and student expectations for the following school physics lecture. Literature study activity is a process of theoretical analysis related to some variables that will be applied in research. This literature study analyses two main things: the importance of teaching instruments in energy conservation learning and the teaching instruments that previous researchers have developed.

2.2. Design

The main activities at the design stage consist of three activities: the design of props, the design of expert validation sheets, and the design of a questionnaire on the perception of the users of the props. The props design is visualized as a solar-powered electric car scheme. The validation sheet involves two experts, namely media experts and material experts.

2.3. Development

At the development stage, six main activities were carried out: manufacturing solar electric cars, testing props, preparing expert and material validation sheets, preparing user perception questionnaires, and executing validation tests. Determination of validation criteria either from media experts or from content experts can be obtained using the Aiken equation [28].

$$V = \frac{\Sigma s}{n(c-1)} \tag{1}$$

V is the validation value, s is the difference between the most minor and expert scores, n is the number of experts involved in the assessment, and c is the most significant scale value. The validation value from the data processing results will be a reference in determining the validity of the application that has been developed. The solar electric car as a prop is valid if it meets the minimum requirements for the validation value 1, because the judgement used five rating category and two raters. The effectivity of prop were determined bypercentage of student approval will be calculated using percentage of student perception [29].

2.4. Implementation

At the implementation stage, limited trials were carried out on forty students. They were divided into five groups to try driving a car. After using the electric car to collect data, they filled out a user satisfaction questionnaire according to their respective impressions and experiences.

2.5. Evaluation

An analysis of the data collected at the implementation stage was carried out at the evaluation stage. At this stage, improvements are made to the solar-powered electric car display instrument according to the user's perception. This prop is ready to be used in energy conversion learning activities. All members of this research work together to formulate the results of the perception analysis and make a revision to make the prop of the solar-powered electric car effective.

3. RESULTS AND DISCUSSION

Results and discussion will be presented according to the research stages carried out. In this study, research and development was used which contains several systematic and synergistic steps. Data presentation will be described in five parts, namely analysis, design, development, implementation, and evaluation.

3.1. Analysis

The sources of information used in the analysis are taken from two main activities: field studies and literature studies. These two activities provided helpful information for developing solar electric car teaching aids. Field studies were carried out through observation and interviews. Data from observations and interviews show that energy conservation learning activities have not been facilitated by teaching aids that students can try directly. Learning activities are assisted by animated videos of energy conversion so that students only observe energy changes. In addition, laboratory conditions that are in the process of being repaired cannot facilitate practicum activities using the available mechanics IIC. The impact is that students do not get a learning environment and opportunities to practice their hands-on skills.

The results of the literature study found that several studies had developed teaching aids for energy conversion learning. Several research results found that there were developments in energy conversion teaching aids that still did not provide meaningful learning experiences to students and also did not provide opportunities to calculate the value of the energy converted, so the effectiveness of the energy conversion tools could not be calculated [5], [21], [22].

Based on the results of the analysis of some energy conversion demonstration instruments that have been described, it is found that there are development gaps that can be carried out.

- It added a digital indicator of the amount of energy produced so that it can be determined quantitatively between the number of energy sources and energy used as a form of work.
- They are using renewable energy sources which is abundant in Indonesia through the media of solar cells, which will be used as an energy source in electric cars.
- Utilizing the prop in learning requires expert validation and user perceptions to support learning outcomes.
- The energy conversion prop focuses more on converting solar energy into motion energy.

3.2. Design

The props design was visualized in a solar electric car scheme shown in Figure 1. The main components of electric cars consist of solar panels, charge controllers, batteries, DC motors, and car frames. Solar cell panels function to absorb the sun's heat, which is then converted into electrical energy. The charge controller produces a stable output voltage from the solar cell (voltage stabilizer), which is then supplied to the battery. The battery is a power source to drive the motor the DC motor functions as a driving machine. The rotation of the engine is then used to turn the car wheels.

The solar electric car uses three panels, each with a power capacity of 50 WP. One solar panel is placed obliquely on the front, and two panels are placed on top across the frame of the solar cell car. This solar electric car has four wheels, two on the front and two on the back. Each wheel on this solar cell car has a diameter of 14 inches. The permanent magnet DC motor is positioned at the rear parallel to the wheel axle. The permanent magnet DC motor shaft and wheel shaft are connected using a pulley and belt mechanism. The small pulley is placed on the permanent magnet DC motor shaft, and the large pulley is placed on the rear axle.

The media expert validation sheet contains many questions that accommodate several aspects of the assessment, namely the visual instrument's efficiency, the optical instrument's accuracy, aesthetics, durability, and safety for the user. In contrast, the material expert validation sheet will contain questions covering three aspects of the assessment: suitability, clarity, and completeness. All validation sheet assessments are expressed in grades using a Likert scale. At the same time, the user perception questionnaire design developed in this study will contain five aspects of responses, including learning motivation, potential support for understanding the concept of energy conversion, operation and performance of props, and visual quality. Assessment of user perceptions will be expressed as a Likert scale rating.

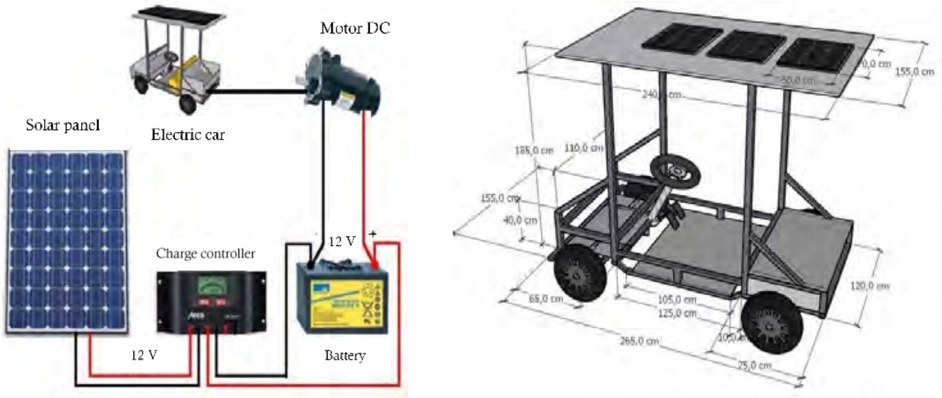
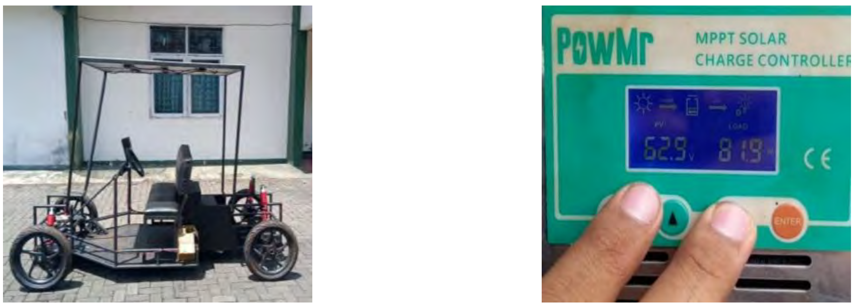


Figure 1. Scheme of solar powered electric car

3.3. Development

This stage includes creating resources and activities in compiling programs or application readiness [30]. At this stage, the production of electric cars is carried out according to the designs that have been prepared. The electric car that has been produced can be shown in Figures 2(a) and 2(b). Figure 2(a) shows the complete electric car, while Figure 2(b) depicts the energy stored from the solar panels. After the electric car is built, limited trials are carried out to ensure that the electric car can be used and there are no problems. The results of this trial found several obstacles, including the microcontroller and the motor, which get hot quickly after being used for 10 minutes. In addition, damage to the electric motor teeth was found, causing it to slip when used. Several improvements were made from the results of this trial, including repairing the microcontroller's electrical components and replacing the motor's gears by changing the reinforcing bolts.



(a) (b)

Figure 2. Components of electric car (a) solar-powered electric car prop and (b) information panel energy stored in batteries from solar panels

After the repair is carried out, the electric car can function correctly. The next activity is validation. One way to achieve content validation is to involve a panel of experts on the subject to be measured [31]. Expert judgment is carried out using an instrument validation sheet. Two media experts and material experts validated props to assess the suitability of the teaching aids as learning media and the suitability of the material that can be conveyed through teaching aids. Validity can be used to ensure that these props can be used in learning according to their concepts and objectives [32].

The results of the expert judgment can be shown in Table 1. Table 1 show the results of processing the assessment data of media and material experts with a value of V of 1. This value has met the minimum requirements for the validation value carried out by two raters using five rating scales. Based on this data, the solar electric car as an energy conversion teaching tool is valid for learning.

Table 1. Results of media and material experts' validation

Raters	Aspects of media										Aspects of material					
	Endurance		Accuracy		Effectiveness		Safety		Aesthetic		Learning objectives		Student needs		Concept understanding	
	R	s	R	s	R	s	R	s	R	s	R	s	R	s	R	s
1	5	4	5	4	5	4	5	4	5	4	5	4	5	4	5	4
2	5	4	5	4	5	4	5	4	5	4	5	4	5	4	5	4
∑s	8		8		8		8		8		8		8		8	
V	1		1		1		1		1		1		1		1	

3.4. Implementation

At the implementation stage, the use of solar electric cars is carried out to learn energy conversion. The number of students involved in this implementation amounted to 20. In the implementation, students are divided into five groups. Each of them used electric cars twice to measure the efficiency of changing light energy into electrical energy and the efficiency of converting electrical energy into motion energy.

The efficiency of converting light energy into electrical energy is determined by measuring the current and voltage strength of the battery and that produced by the solar panel. To assess the efficiency of converting electrical energy into motion energy, each group calculates the average speed of an electric car on a straight line to find the average kinetic energy and calculates the change in electrical energy stored in the battery. Each group of students takes measurements and analyses the experimental data to be compiled as a report on the experiment's results.

3.5. Evaluation

The evaluation stage is the last carried out in product development. At this stage, it is carried out to examine the ease and effectiveness of electric cars in learning energy conservation. This stage follows Stappenbelt's opinion that the effectiveness of a tool used in learning can be determined by the perception of its users [33]. At the evaluation stage, data was collected on students' perceptions of using a solar electric car as input for improvement. Data on student perceptions were collected using a Likert scale questionnaire. The results of student perceptions are shown in Table 2.

Table 2 shows that the average percentage of student perceptions is 72.5, with a high perception category. The students responded positively to the solar-powered electric car as an energy conversion teaching aid. The highest percentage of student perceptions is that "The prop makes energy conversion learning activities run effectively." They admit that this is their first experience learning energy conversion using teaching aids that they can do directly. It provides a memorable experience to support the strengthening of memory storage for the concepts conveyed.

Table 2. Results of student perceptions

No	Assessment aspects	%	Category
1	The prop has an attractive shape	67.5	Moderate
2	The prop can be used easily	71	High
3	The prop is safe for use in learning	65	Moderate
4	The prop produces data that helps students understand the concept of energy conservation	78	High
5	The prop makes energy conversion learning activities run effectively	82	High
6	The prop makes students more enthusiastic about learning	75	High
7	The prop increased student's curiosity about the concept of energy conversion	79	High
8	The prop train student's process skills in learning activities	65	Moderate
9	The prop provides new experiences in learning activities	72.5	High
10	The prop can accommodate students' learning style	70	High
	Mean	72.5	High

3.6. Discussion

A solar electric car as a physics learning prop has been developed using the ADDIE model. This model has been widely used in forming various components involved in learning activities. This model is considered an effective model for producing educational products. It has been used to develop curricula in library instruction and online continuing education [34]. By using this model, Widyastuti and Susiana [35] has succeeded in developing teaching materials in actuarial mathematics. From the results of his research, the teaching materials developed had a good expert validity value and received positive responses from students as users. Wibawa *et al.* [36] also used the ADDIE model, which developed interactive educational multimedia using lectora inspire. The results of his research show that the ADDIE model provides direction to produce a scholarly product that suits the needs of students so that the product has a high value. The validity of the product developed has met the expected eligibility criteria and received a high approval response from students with a percentage of 85.9% and optimal satisfaction with a portion of 84.375%. The tools' validity is fundamental to note to see the suitability between students' needs for the media and the development of the device to be used optimally to achieve learning goals [37].

In this study, the focus of testing teaching aids was emphasized on the validity of the teaching aids and students' perceptions of the tools used. The results of this study indicated that the validity of the tools developed was determined to include several aspects according to their expertise. The assessment of media and material experts obtained with the Aiken formulation found that the teaching aids set met the eligibility criteria for teaching aids in appearance, convenience, and suitability for learning needs. This research is in line with several other research. Gunawan *et al.* [38], who developed props made from second-hand materials, determined the tool's feasibility as a learning media reviewed by material experts and media experts. The feasibility assessment of teaching aids is determined based on the percentage of validator approval with the proportion of media experts and material experts, 90% and 95%, respectively. Al Asy'ari *et al.* [39] have also developed a prop Atmega 16-based momentum with a sensor system to support physics learning activities. Determining the quality of the teaching aids developed is based on expert validity and students' perceptions as users. The developed tool has a validity level of 85% and obtains a percentage of approval for the use, reaching 81.9%.

The second factor used as a benchmark for the quality of the tool being developed can be determined from the students' perceptions as users. This study found that the approval of students as users reached 72.5 % in the high category. This result shows that students are satisfied with using solar-powered electric cars. Students' perceptions of props are fundamental to delivering student satisfaction in learning [40]. Students' satisfaction with braces will increase their readiness to accept more complex learning challenges and train themselves with additional skills [41].

Conversely, if students have negative perceptions, it will affect their learning motivation, hinder learning activities, and tend not to achieve learning goals [42]–[44]. Students' perceptions of using visual aids in learning can be influenced by various factors, including social, cognitive, and teaching presence [45]. Ke and Kwak [46] identified several elements of student perception: authentic learning, active learning, learner autonomy, learner relevance, and technological competence. Student perceptions can also be influenced by the instructor's characteristics and the learning facilities' condition [47].

4. CONCLUSION

Energy conversion props in the form of a solar-powered electric car were developed using the ADDIE model. It involves the process of analyzing the needs of energy conversion teaching aids according to learning objectives, designing solar-powered electric cars as energy conversion teaching aids, developing a solar cell-powered electric car and validation tools and student perception questionnaires, piloting the use of solar electric car in learning, and evaluating the use of teaching aids. Based on the results of developing a solar electric car as an energy conversion learning prop, it has been effective for learning following the results of expert validation and user perceptions. The validation results of media and material experts show that the value of V meets the criteria for valid teaching aids. Student perceptions have also shown positive responses, with the average perception in the high category. The results of this research will be beneficial in optimizing renewable energy conversion learning and following technological developments. Learning with practical props will provide students with direct experience and memorable learning, so they are expected to achieve learning objectives.

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