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Simple Floating Ocean Wave Energy Converter: Developing Teaching Media to Communicating Alternative Energy

Muhammad Satriawan[1,*], Rosmiati[2]
[1]Universitas Negeri Surabaya, Surabaya, Indonesia
[2]STKIP Bima, Bima, Indonesia

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ABSTRACT
Research aims to develop teaching media in communicating alternative energy to students who are in high school. The teaching media developed as a prototype converter of ocean wave energy into electrical energy. This Converter is focused on helping students understand concepts and technologies in utilizing ocean wave energy as an alternative energy source. The development stage adopted the ADDIE model, which is limited to the analysis, design, and development stages. The data obtained are in the form of design validation data, trial data, and product assessment data. The data were analyzed using descriptive statistics. Based on the results of data analysis, it is found that (1) the converter design is feasible to be developed with a few additions to the transmission section to produce higher RPM; (2) the resulting converter functions correctly with the output voltage of 5 to 9 volts in the artificial wave pool test and reaches 8 to 12 volts; (3) for product assessment, it was found that the Converter produced was suitable to be used as a teaching medium to communicate concepts and technology in utilizing ocean wave energy as an alternative energy source. So, teaching media in the form of a wave energy converter could be used as an alternative to communicating the concept of using ocean waves as an alternative energy source. The implication of this research is that it can be used as a model or initial example in developing learning media related to alternative energy and can even be used as a model in developing converters on a larger scale so that the wider community can use them.

INTRODUCTION

Electrical energy is energy that cannot be separated from human life. Currently, electrical energy is used not only as lighting but as a source of energy to operate all electronic goods (Ryu et al., 2019; Shaqsi et al., 2020; Satriawan et al., 2021). Based on data from the Ministry of Energy and Mineral Resources of the Republic of Indonesia, there is a 100% increase in electricity consumption from 2007 of 0.6 KWH/capita to 1.2 KWH/capita in 2020. This shows that there has been massive exploitation of coal in the last few decades, where the number of new rock reserves is limited to use, so it is predicted that these reserves will run out in the next 16 years (Perkins et al., 2020; Welsby et al., 2021; Zhao & Luo, 2018). Therefore, this situation requires alternative steps to anticipate the energy supply shortage for community needs.

Renewable energy is an alternative to conventional energy, which is produced from natural sources that are environmentally friendly, easy to obtain, and sustainable such as sun, wind, water, bioenergy, and many more (Shahbaz et al., 2020; Guo et al., 2018). Indonesia is one of the strategic countries for the development of renewable energy because Indonesia is a tropical country and an archipelagic country. The Indonesian ocean area along the southern coast of Java to Nusa Tenggara is a location that has a significant enough wave energy potential ranging from 10 - 20 kW/m, and even at some points in Indonesia, it can reach 70 kW/m in some locations (Rizal & Ningsih, 2020; Thahlil & Singgih, 2022). However, this condition has yet to be fully utilized by the Indonesian government to switch to alternative energy. This is due to the need for more human resources willing to have a career in alternative energy. Therefore, it is essential to introduce alternative energy to the Indonesian people early.

Potential energy resources will develop well in line with the quality of human resources. Education is an effort to prepare a better future generation, namely a generation with several knowledge, skills, and attitudes that can deal with developments that occur in society (Zamora-Polo & Sánchez-Martín, 2019). One of the educational efforts to prepare a generation that can contribute to the development of renewable energy technology is through the school-based energy literacy movement (Dangkua et al., 2022; Lowan-Trudeau & Fowler, 2022). Energy literacy is critical to be taught from elementary to high school because, as previously explained, energy is part of the life of living things whose management requires precision and wisdom (Rohmatulloh et al., 2021). However, the reality is that energy literacy at the elementary to high school level is still lacking. This follows research by Bamisile (2020) that high school students in Nigeria have a low level of energy literacy, which is only 47.3%. Therefore, for long-term interest, it is necessary to increase energy literacy activities for the younger generation, especially for students in both primary and secondary schools.

Several genuine efforts have been made to provide energy literacy, namely using the geospatial curriculum approach (Bodzin et al., 2013); energy through fieldwork (Van der Horst, 2016); through an integrated model approach (Akitsu & Ishihara, 2018), project-based learning (Karpudewan & Ponniah, 2016; Radulović, at al., 2021); through collaborative learning (Gladwin et al., 2022); through the analytical hierarchy process (Chen et al., 2013). The efforts made by these researchers only literate the concept of alternative energy and focus on raising students' awareness regarding energy use. Of course, this is very well done, but what is needed now is human resources who not only have an awareness of the use of energy but also need human resources who can contribute to the development of alternative energy technologies.

In addition, from the results of these studies, this is the first time anyone has tried to use teaching media in the form of mini alternative energy technology to introduce alternative energy to students. Even though the use of such media, besides being able to impact students' knowledge related to the concept of alternative energy, can also provide literacy to students related to alternative energy technology. Therefore, it is necessary to carry out a learning innovation that can provide knowledge related to alternative energy technology Bamisile (2020). One of the alternatives is to design a lesson that provides a direct experience to students related to alternative energy through appropriate learning media. SuiTable teaching media will make it easier for students to understand the concepts that will be conveyed.

Based on this description, the researcher proposes to develop a simple teaching media related to alternative energy technology. This media is expected to assist students in understanding the concept of alternative energy, especially regarding the use of ocean wave energy as an alternative energy source.

RESEARCH METHOD

This type of research is Research and Development (research and development), a process to develop a new product or improve an existing one, which can be accounted for. The ADDIE development model uses the development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Ranuharja et al., 2021; Dwitiyanti et al., 2020; Hasan et al., 2021). The research on the development of the ADDIE model was carried out only until the Development stage because the purpose of this research was only to develop and produce a valid learning media to be implemented based on validator assessments and trials. The research design is shown in Figure 1.

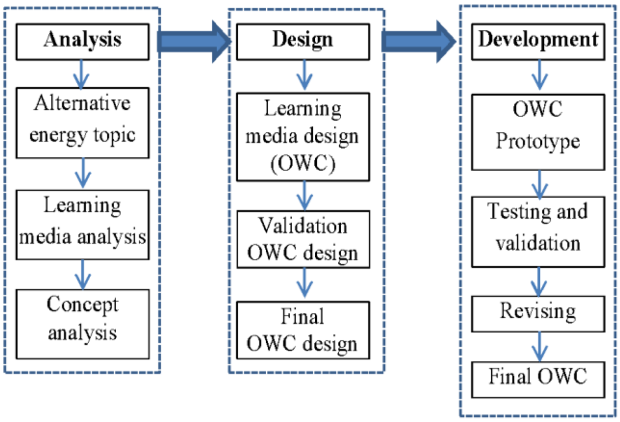

Figure 1. Research design.

The stages of development research, namely the analysis stage, include an analysis of product development consisting of the topic analysis, learning media analysis, and analysis of the physics concepts used in the developed Converter (Kristanto & Mariono, 2019). The design stage is designing a draft of alternative energy teaching media using ocean wave energy as a source of electrical energy in the form of a simple converter and designing a validation sheet for media experts and material experts (Sutadji, 2020). Validation of the instrument used as a product assessment rubric given to material and media experts. The development stage is developing media that produces a product as a simple ocean wave energy converter (Satriawan et al., 2020). It can be used as a teaching medium in conveying the concept of alternative energy, especially in using ocean wave energy as an alternative energy source. Furthermore, the developed tools were validated by experts and tested to determine their functionality. Furthermore, improvements were made based on the validation and testing results.

Data were collected using expert validation sheets and tool test sheets. Expert validation was carried out by five experts consisting of 3 electric experts and two learning media experts. Meanwhile, the Converter was tested on an artificial wave pool with dimensions of 3 m long, 1 meter wide, 1 meter high, and a wave height of 10 to 25 cm. Furthermore, a trial was carried out on one of the beaches with waves with a height of 0.5 to 1 meter. The benchmark for the functioning of the Converter is the output in the form of current and voltage values generated by the Converter.

Furthermore, the data from the test results were analyzed descriptively, and the data from the expert validation were analyzed using the content validity ratio (CVR). The CVR value, according to Hassan (2018), can be calculated by equation 1.

$$CVR = \frac{n-N/2}{N/2} \qquad (1)$$

Where N is the number of panel experts, and n is the number of experts who say appropriate. The media is feasible if the calculated CVR value exceeds the critical CVR. According to Hassan (2018), for raters of 5 people, the critical CVR value is four people. This means that the media is said to be suitable for use if all raters (5 people) must answer yes, and conversely, if there is one rater who answers no, then the media is not suitable for use or must be repaired.

RESULTS AND DISCUSSION

Analysis stage

Topic selection

At this stage was an analysis related to alternative energy following the region's potential. This is intended to introduce the potential of alternative energy sources owned by the region. It is hoped that one day students who study this topic will be interested in developing potential alternative energy technologies in their area. Based on the analysis results, considering the potential in the area, three topics are most appropriate to be developed: solar energy sources, wind energy sources, and ocean wave energy sources. However, this research focuses on developing particular media for ocean wave energy as an alternative energy source for learning outside the classroom (on the beach).

Furthermore, location observations were conducted to determine the trial's location, the learning location, and the developed media's characteristics. This is done to determine the characteristics of ocean waves. Based on observations, in several places along the coast of Bima at a certain depth, the wave height reaches 10 to 25 cm, with waves occurring 40 to 60 times per minute. The wave characteristics are used as one of the factors considered in making media, so that teaching media function properly (Satriawan et al., 2020).

Teaching media analysis

At this stage, an analysis is carried out to what extent the teaching media related to ocean wave energy as an alternative energy source has been previously developed. Based on the results of the journal analysis, only two articles developed teaching media to communicate the topic of ocean wave energy as an alternative energy source, namely wave energy virtual reality media (WEVR) (Grivokostopoulou et al., 2016) and wave energy converter kits (WECK) (Satriawan et al., 2020). WEVR media was developed to be used in classroom learning, and the development of this media requires substantial funds. In contrast to the WECK media developed for learning outside the classroom, the development costs are very cheap. However, the WECK media is straightforward and difficult to use directly on ocean waves.

Based on the analysis of the two media, the media developed in this study refers to the WECK media. The media developed is different from the existing ones and is certainly easier to use directly on shallow ocean waves so that students can see firsthand how the principle of the media works.

Analysis of physics concepts used in the media

1) Ocean wave energy concept

The physical concept used in the media is the concept of ocean waves by utilizing the total energy (ET) of deep ocean waves. According to the Airy wave theory, the total energy of deep ocean waves can be determined by the formula (1) (Satriawan et al., 2021).

$$E_T = E_P + E_K = \frac{1}{4}\rho g A^2 + \frac{1}{4}\rho g A^2 = \frac{1}{2}\rho g A^2 \qquad (2)$$

with

$$A = \frac{H}{2} \qquad (3)$$

$A = \frac{H}{2}$Where Ek is the kinetic energy of the wave (J); EP is the wave potential energy (J);

is density (kg/m^3); H is the height of the ocean wave (m); g is the gravity acceleration (m/s^2), and A is the amplitude of the wave (m).

2) RPM transmission concept through rotational dynamics

In addition, the converter system developed also uses the concept of rotational dynamics, namely the relationship between two wheels. The goal is for the motion energy transmission system to rotate the dynamo larger to produce a large output voltage. The wheel relationship is an axle relationship and a chain relationship, as shown in Figure 2. Based on Figure 2, for the connection of two-axle wheels, ω_L=ω_S $\omega_L = \omega_s$ and two wheels

connected by a chain apply $\omega_L R_L = \omega_S R_S$ $\omega_L . R_L = \omega_S . R_S$ whereω_L ω_L is the angular

velocity of the large wheel (rad/minute), ω_S is the angular speed of the small wheel (Rad/minute), R_L is the radius of the large wheel (m), and R_S is the radius of the small wheel (m). So, to increase the angular speed or the RPM of the dynamo shaft, the RPM on the big wheel must be transmitted using a chain to the small wheel (Bhat et al., 2019). The smaller the wheel radius in line with the dynamo shaft, the greater the resulting RPM.

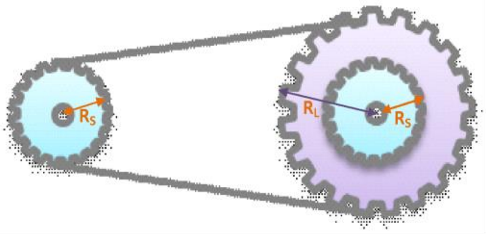

Figure 2. Wheel connection.

3) DC Dynamo Concept

The size of the voltage generated by the dynamo on the Converter is dependent on the RPM value connected to the dynamo shaft. The greater the RPM produced in the final transmission, the greater the output in the form of voltage generated by the dynamo, as described by the formula (4) (Putra et al., 2021; Lubis et al., 2019).

$$V = C\,n\,\Phi + I_a R_a \tag{4}$$

Where V is the output voltage (volts); C is the motor constant; n is the number of revolutions (RPM); Φ is the motor flux (Weber); I_a is the armature current (ampere); and R_a is the anchor resistance (ohm).

Design stage

Converter design

At this stage, the media design will be developed by considering the results of the analysis in the first stage, which includes the characteristics of ocean waves, existing media, and physical concepts that will be applied. The initial design of the developed media is shown in Figure 3.

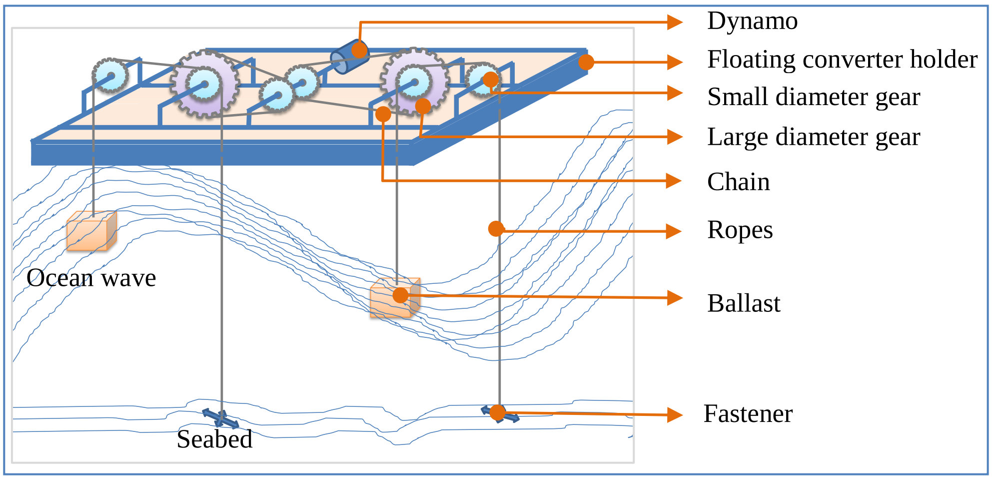

Figure 3. The initial design of the Converter.

Figure 2 shows the components of the developed converter, namely (1) Dynamo functions to produce output voltage; (2) Floating converter holder functions as a system holder or components as well as a buoy that captures the total energy of ocean waves; (3) Small diameter gear serves to receive energy from the floating converter holder which is then converted into RPM, with the type of gear used in this section is a single-bearing bicycle; (4) Large diameter gear serves to continue the RPM from the small diameter gear, then the RPM is enlarged through the transmission to a smaller gear which is then forwarded to the dynamo through the axle connection with the armature shaft; (5) Chain serves to connect two wheels; (6) Ropes function as ropes to tie the seabed and tie ballast; (7) Ballast functions as ballast as well as a counterweight so that the chain does not detach from the gear, and (8) Fasteners function as anchors on the seabed.

Converter working principle

The working principle of the developed Converter is to utilize the lifting force of the ocean waves. The propagation of ocean waves with a height of h hitting the front of the converter mount vertically drives a small gear to produce RPM. The RPM of the small gear is transmitted to the large gear in axis with the small gear so that it has the same amount of RPM. The RPM on the big gear is transmitted again to the smaller gear so that the RPM on the small gear becomes bigger (Bhat et al., 2019; Ambre et al., 2019). This significant RPM rotates the dynamo shaft to produce an electric voltage. In this condition, the rear gear system has not operated because the seat is right on the wave valley at the rear. Furthermore, ocean waves propagate against the rear of the mount so that the gear system at the rear of the mount operates as the front gear system does. At the same time, the front gear system does not work because it is right in the wave valley. And so on, the gear system works continuously, and the dynamo still produces voltage.

Validate converter design

At this stage, the converter design is validated by 5 (five) expert validators. The validated components are (1) the suitability of the tool designed with the physics concept used; (2) the functioning of the Converter; (3) Estimating the efficiency of the output generated by the Converter; (4) The feasibility of the Converter as a teaching medium.

Table 1. Expert validation results on the initial design of the Converter.

Aspect assessed	Validator					Sum	CVR
	1	2	3	4	5		
The suitability of the tool designed with the physics concept used	1	1	1	1	1	5	1
The functionality of the Converter	1	1	1	1	1	5	1
Estimated output efficiency of the Converter	1	1	1	1	1	5	1
Feasibility of Converter as teaching media	1	1	1	1	1	5	1

Based on the validation results, the converter design is feasible to develop. This is shown in Table 1, where all validators assign a value of 1 to the assessed item. It means the design is proper to develop (Amarulloh, & Dzakiria, 2021; Handayani et al., 2022). However, before being developed, it is necessary to pay attention to several notes, namely: (1) the dimensions of the tool to be developed must be clear because it affects the working system of the tool, especially the cross-sectional area of the converter holder; (2) so that the final RPM produced is significant, at the end of the tool transmission system it is necessary to install a large diameter wheel with a small wheel at the end of the converter transmission, then the dynamo shaft is connected to the diameter wheel through a belt.

Development stage

Converter manufacture

The manufacture of the Converter begins by gathering all the components, as shown in Figure 3. These components can be obtained on broken bicycles or at flea markets. However, components such as small diameter gear, in this case, the bicycle bearing, must be suitable because it functions as the main driver of the system, so it should be used in new conditions. Furthermore, welding machines, iron cutting tools, iron glue, rulers, and iron drills are used to manufacture the Converter. After everything is in place, the next step is making a frame for the converter mount. This frame is made of iron so that all components are correctly installed and do not move. However, a pipe is installed at the bottom with both ends closed to keep the converter holder floating at sea level. Next, all components are assembled as in the design in Figure 4.

Figure 4. The results of the developed Converter.

Figure 4 shows a converter that has been developed and is ready to be tested. The Converter was developed by considering a suggestion from expert validators at the design stage so that the converter display differs from the initial design. The difference is seen in the large wheels at the end of the transmission system from the front and rear. The purpose is to increase the RPM, which will be forwarded to the dynamo to produce a larger voltage (Bhat et al., 2019; Ambre et al., 2019).

Testing stage

At this stage, experiments were carried out on an artificial wave pool with dimensions of 3 m long, 1 meter wide, and 1 meter high. The test results show that the Converter functions correctly, and the resulting voltage continuously reaches 5 to 9 volts. Furthermore, the Converter was tested in the sea by involving students, as shown in Figure 5.

Figure 5. Testing converter on the ocean wave.

Based on the results of the data analysis, the maximum voltage generated by the dynamo is 12 volts. This indicates that the resulting voltage is the maximum measured voltage for the DC 775 dynamo type, where the maximum output is 12 volts (Ramadhan, 2022; Riyanto et al., 2022). In addition, from observations during the test, several factors affect the value of the voltage generated by the Converter, namely wave height, wave frequency, and wave period. The more considerable the wave height is generated, the higher the voltage and otherwise (Moretti et al., 2018; Singh et al., 2020). If seen from the wave frequency side, it was found that the greater the wave frequency with the same wave height, the voltage generated by the Converter is more stable (Zhang et al., 2019). Likewise, the resulting voltage tends to be stable when the wave period is small.

At this stage, it was also observed how the responses of the students involved during the trial were observed. Based on the results of interviews with students, learning at the beach is meaningful and fun (Bakri et al., 2020; Waluya & Suyitno, 2019). This is because students not only gain new knowledge, but this learning activity is like it has never been done before. This is in line with Susanti et al.'s (2020) research, which reveals that learning is fun when the learning situation is not monotonous.

In addition, during the pilot process, students are given the opportunity and freedom to directly interact with the Converter, such as determining the position of the Converter and measuring the voltage generated by the Converter. This activity certainly provides real experience to students so that students understand how the process of converting wave energy into electrical energy through the Converter is used. Therefore, it can be concluded that to help communicate the concept of alternative energy, especially the concept of using ocean wave energy as an alternative energy source, teaching media in the form of a converter prototype can be used following the model development stages of analysis, design, and development.

CONCLUSION

Based on the results of research and discussion, it can be concluded that the teaching media developed in the form of a prototype ocean wave energy converter is suitable to help communicate the concept of alternative energy, especially regarding the use of ocean wave energy as an alternative energy source. The disadvantage of this research is that the converter development process takes a long time and can only be used for one material, namely ocean wave energy. This research implies that it can be used as a model or initial example in developing learning media related to alternative energy and can even be used as a model in developing a converter with a larger scale so that the wider community can use it. Recommendations for further research from the Converter that has been produced can be made virtual so that it can explain concepts that cannot be explained or observed through converters.

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***Dr. Muhammad Satriawan, M.Pd (Corresponding Author)**
Department of Physics,
Universitas Negeri Surabaya,
Ketintang Street, Gayungan Districts, Surabaya City, West Java, 60231, Indonesia
Email: muhammadsatriawan@unesa.ac.id

Dr. Rosmiati, M.Pd
Physics Education Study Program,
STKIP Bima,
Piere Tendean Street, Mpunda Districts, Bima Town, West Nusa Tenggara, 84111, Indonesia
Email: rosebiru1@gmail.com