Development of Thermal Energy Conversion Devices into Electrical Energy as Physics Learning Teaching Aids

D K Umam, S Saehana*, A Kade, and Yunanli

*Sub-Department of Physics Education, Faculty of Teacher Training and Education, Universitas Tadulako, Jl. Soekarno Hatta KM. 9 Kampus Bumi Tadulako Tondo Palu-Central Sulawesi, Indonesia

*sahrulsaehana@gmail.com

Abstract. This research aimed to produce a device for converting heat energy into electrical energy as a teaching aid for physics. This research process is development research, which refers to the Research and Development (R&D) model. The instrument used was a questionnaire with a five Likert scale, which addressed media experts, material experts, physics teachers in SMA Negeri 2 Sigi, and class XII MIA SMA Negeri 2 Sigi students. The product quality data obtained were analyzed using descriptive analysis. Based on the analysis of the media expert's assessment, the quality of the product obtained a percentage value of 87.69% with the interpretation of "Very Good". Based on the analysis of the assessment by material experts, the quality of the product obtained a percentage value of 84.44% with the interpretation "Very Good". For the results of the physics teacher's response, a percentage value of 86.00% was obtained with the interpretation "Strongly Agree". For the results of the responses of class XII MIA students in the limited test, a percentage value of 83.56% was obtained with the interpretation "Strongly Agree". The test results and questionnaire analysis showed that the heat energy conversion device developed into electrical energy was feasible to use.

1. Introduction

Physics learning places concepts and practicum as the center of learning because the Physics material is closely related to abstract concepts, so it is necessary to involve hands-on activities in topic delivery. The demonstration given in the form of practicum, either using simulation or laboratory practicum, is an effort the teacher uses to connect the concepts of Physics with real life and make learning more meaningful [1]. In addition to hands-on activities, teaching aids or learning media are also a part that can deliver abstract concepts to be more concrete and realistic [2]. The use of teaching aids can also increase student engagement because they feel happy and enthusiastic in using tools related to everyday life [3]. Besides being used as equipment to assist teachers in transferring learning materials, teaching aids are also intended to increase interest and motivation in learning and make it easier to understand the concepts being studied [4]. Increasing engagement in learning is essential because it is related to learning outcomes and performance [5,6].

One of the materials that contain abstract concepts but is closely related to everyday life is the concept of electricity [7,8]. Several previous studies have shown the positive influence of virtual and real laboratories on materials about electricity on student learning outcomes [9–11]. However, the majority of schools in Indonesia that have limited facilities cannot apply laboratory practicum to students. Because of these limitations, it is necessary to develop accessible and inexpensive teaching aids.
This study aims to develop teaching aids for the conversion system of heat energy into electrical energy. These systems are commonly referred to as direct energy converters (direct-energy converters). This teaching aid can solve the limitations of the material for electricity generators, which is indispensable in learning physics. It is necessary to enrich students' knowledge about sources of electrical energy other than chemical, nuclear, and solar energy. By understanding the material, students have a more significant opportunity to find alternative sources of electrical energy in their daily lives.

2. Method
This research belongs to the type of research and development known as Research and Development (R & R&D), which is a research model used to produce certain products and test their effectiveness [12]. The research began with the design process or a quick overview of the tool. Then, the preparation of the tools and materials to be used and the making of tool designs. Based on the results of consultation and guidance, the tool's design turned into a complete product.

The tool designed was then validated by two expert validators from Physics Education of FKIP Tadulako University using an assessment instrument in the form of responses that will be used as a reference to improve the product. After the revision stage was carried out, it was continued with a limited trial conducted by physics teachers and 30 students of class XII MIA SMA Negeri 2 in Sigi district by filling out a response scale about three months.

The data analysis technique of the research results went through several stages. First, collect questionnaire data, then identify and group according to the assessment and answers on the questionnaire. Second, the data is processed in the form of a percentage. Third, the data were analyzed using quantitative descriptive techniques expressed in the distribution of scores and percentages against the rating scale categories [1], as shown in Table 1.

Table 1. Likert scale and interpretation of product evaluation

| Percentage (%) | Score Scale | Interpretation |
|----------------|-------------|----------------|
| 0 – 20         | 1           | Very Bad       |
| 21 – 40        | 2           | Deficient      |
| 41 – 60        | 3           | Sufficient     |
| 61 – 80        | 4           | Good           |
| 81 - 100       | 5           | Very Good      |

3. Results and Discussion
3.1. Observation Results of Electrical Energy
The research results that the researchers developed were a device for converting heat energy into electrical energy as a teaching aid for physics. This tool can generate electrical energy by changing the temperature difference between the two sides (hot and cold sides heatsink). The results obtained when using the tool were that the LED (as an indicator) could light up and see the current (I) and voltage (V) using a multimeter.

The observations of electrical energy produced by heat sources of candles with different amounts can be seen in Tables 2, 3, 4 and 5.

Table 2. Results of observation of electrical energy produced with a heat source of 1 candle

| No. | Tp (°C) | Td (°C) | Δt (°C) | V (Volt) | I (A)   | P (Watt) |
|-----|---------|---------|---------|----------|---------|----------|
| 1   | 52      | 40      | 12      | 2.86     | 0.00090 | 0.00257  |
| 2   | 52      | 40      | 12      | 2.86     | 0.00090 | 0.00257  |
| 3   | 52      | 41      | 11      | 2.84     | 0.00088 | 0.00250  |
| 4   | 51      | 41      | 10      | 2.81     | 0.00079 | 0.00222  |
| 5   | 51      | 41      | 10      | 2.80     | 0.00078 | 0.00218  |
| Mean Score | 51,6 | 40,6 | 11 | 2.834 | 0.00085 | 0.00241 |
Table 3. Observation results of electrical energy produced with 2 candles heat source

| No. | $T_p$ ($^\circ$C) | $T_d$ ($^\circ$C) | $\Delta t$ ($^\circ$C) | V (Volt) | I (A)   | P (Watt) |
|-----|------------------|------------------|------------------------|----------|---------|----------|
| 1   | 77               | 41               | 36                     | 10.20    | 0.00362 | 0.0369   |
| 2   | 77               | 42               | 35                     | 10.08    | 0.00334 | 0.0337   |
| 3   | 77               | 42               | 35                     | 10.04    | 0.00333 | 0.0334   |
| 4   | 76               | 41               | 35                     | 10.00    | 0.00332 | 0.0332   |
| 5   | 74               | 40               | 34                     | 9.98     | 0.00330 | 0.0329   |
|     | Mean Score       | 76.2             | 41.2                   | 35       | 10.06   | 0.00338  | 0.0340   |

Table 4. Observation results of electrical energy produced with 3 candles heat source

| No. | $T_p$ ($^\circ$C) | $T_d$ ($^\circ$C) | $\Delta t$ ($^\circ$C) | V (Volt) | I (A)   | P (Watt) |
|-----|------------------|------------------|------------------------|----------|---------|----------|
| 1   | 92               | 41               | 51                     | 13.61    | 0.00636 | 0.0866   |
| 2   | 92               | 42               | 50                     | 13.60    | 0.00630 | 0.0860   |
| 3   | 91               | 42               | 49                     | 13.60    | 0.00628 | 0.0854   |
| 4   | 91               | 42               | 49                     | 13.60    | 0.00626 | 0.0851   |
| 5   | 90               | 41               | 49                     | 13.60    | 0.00625 | 0.0850   |
|     | Mean Score       | 91.2             | 41.6                   | 49.6     | 13.602  | 0.00629  | 0.0856   |

Table 5. Observation results of electrical energy produced with 4 candles heat source

| No. | $T_p$ ($^\circ$C) | $T_d$ ($^\circ$C) | $\Delta t$ ($^\circ$C) | V (Volt) | I (A)   | P (Watt) |
|-----|------------------|------------------|------------------------|----------|---------|----------|
| 1   | 99               | 46               | 53                     | 13.96    | 0.01448 | 0.202    |
| 2   | 99               | 46               | 53                     | 13.95    | 0.01448 | 0.202    |
| 3   | 99               | 46               | 53                     | 13.95    | 0.01448 | 0.202    |
| 4   | 98               | 46               | 52                     | 13.95    | 0.01447 | 0.202    |
| 5   | 98               | 46               | 52                     | 13.92    | 0.01447 | 0.201    |
|     | Mean Score       | 98.6             | 46.6                   | 52.6     | 13.946  | 0.01447  | 0.202    |

The relationship between temperature and the potential difference can be seen in Figure 1. On the other hand, the relationship between temperature difference and electric current is presented in Figure 2.

![Figure 1](image1.png)

**Figure 1.** Graph of the relationship between temperature and potential difference
After revising, the development of the tool was then continued, with validation from media experts and material experts. The products produced by researchers in the tool's design for converting heat energy into electrical energy are shown in Figure 3.

![Figure 3. Thermal energy conversion device into electrical energy](image)

### 3.2. Assessment Results of Thermal Energy Conversion Devices into Electrical Energy

#### 3.2.1 Assessment by media experts

The validation results by media experts using several aspects can be seen in Table 6. The results of the assessment on each aspect were as follows: the efficiency of teaching aids was in a "very good" category (VG) with a percentage score of 90%; aesthetic aspects gained "good" criteria (G) with a percentage score of 80%; the durability aspect of the teaching aids was in "good" criteria (G) with a percentage score of 80%; the safety aspect for students included in "very good" criteria (VG) with a percentage score of 85%; and the mean score of the four aspects was 87.69% with "very good" criteria (VG).

| No. | Aspect     | Criteria       | Result    |
|-----|------------|----------------|-----------|
| 1   | Efficiency | Ease of Assembling | Good     |
|     |            | Ease of Use     | Good      |
|     |            | Ease of Transfer | Very Good |
|     |            | Ease of Saving  | Very Good |

![Figure 2. Graph of the relationship between temperature difference and electric current](image)
2 Aesthetics
   Shape
   The Suitability of Teaching Aids With
   Students' Physical Size
   Good

3 Props
   Durability
   Not Easily Loose, Broken or Destroyed
   When Used
   Installation Accuracy of Each Component
   Component Resistance in its Original
   Position.
   Good

4 Safety for
   Students
   Made of Safe Materials (Not Sharp)
   Safe Construction for Students (Not Easy to
   Collapse)
   The use of tools does not require special
   treatment (wearing a mask or gloves).
   No Effect of Harmful Chemicals (Non-
   Flammable, Non-Irritating).
   Good
   Very Good

3.2.2. Assessment by material experts
The results of the material expert assessment carried out using several aspects can be seen in Table 7.

| No. | Aspect | Criteria | Result   |
|-----|--------|----------|----------|
| 1   | The Relationship between Teaching Aids and Teaching Materials | Show Physical Phenomena | Good |
|     |        | Required in Learning Renewable Energy Source Materials | Good |
|     |        | Generate Concepts from Props | Good |
|     |        | Explain the concept of Renewable Energy | Good |
| 2   | Educational Value | The Suitability of Teaching Aids With the Intellectual Development of Students | Very Good |
|     |        | Easy for Students to Understand Concepts | Good |
|     |        | Teaching Aids Suits the Needs in Learning | Good |
|     |        | Ease For Learners To Improve Skills (Thinking, Speaking And Moving) | Very Good |
|     |        | Fostering Motivation for Students to Study More Actively | Good |

The results of the assessment of each aspect can be seen in Figure 4. Overall, all aspects were in the 80 percent or included in the "Very Good" category. The assessment of the relationship between teaching aids and teaching materials was in the "Very Good" (VG) category with a percentage score of 80%. Aspects of educational value got "Very Good" (VG) criteria with a percentage score of 88%.

![Figure 4. Material experts' assessment chart](image-url)
3.2.3. Assessment by physics teacher
The results of the physics teacher's assessment of the developed product can be seen in Table 8. The results of the assessment of each aspect were as follows: the assessment of the relationship between teaching aids and teaching materials was in the "Very Agree" (VA) category with a percentage score of 85%; the assessment of the educational value got the category of "Agree" (A) with a percentage score of 72%; assessment of the efficiency of teaching aids, and safety aspects got a perfect score of 100% with the category of "Very Agree" (VA); while the aesthetic and durability aspects included the "Agree" criteria (A) with a percentage score of 80%; and the percentage mean score of the six aspects was 86.36% with the criteria of "Very Agree" (VA).

| No. | Aspect                                      | Criteria                                      | Result  |
|-----|---------------------------------------------|-----------------------------------------------|---------|
| 1   | The Relationship between Teaching Aids and Teaching Materials | Show Physical Phenomena                      | Very Agree |
|     |                                             | Required in Learning Renewable Energy Source Materials | Agree   |
|     |                                             | Generate Concepts from Props                  | Agree   |
|     |                                             | Explain the concept of Renewable Energy       | Agree   |
| 2   | Educational Value                           | The Suitability of Teaching Aids With the Intellectual Development of Students | Agree |
|     |                                             | Easy for Students to Understand Concepts       | Very Agree |
|     |                                             | Teaching Aids Suits the Needs in Learning      | Uncertain |
|     |                                             | Ease For Learners To Improve Skills (Thinking, Speaking And Moving) | Uncertain |
|     |                                             | Fostering Motivation for Students to Study More Actively | Uncertain |
| 3   | Efficiency                                  | Ease of Assembling                            | Very Agree |
|     |                                             | Ease of Use                                   | Very Agree |
|     |                                             | Ease of Transfer                              | Very Agree |
|     |                                             | Ease of Saving                                | Very Agree |
| 4   | Aesthetics                                  | Shape                                         | Agree |
|     |                                             | The Suitability of Teaching Aids With Students' Physical Size | Agree |
| 5   | Props Durability                            | Not Easily Loose, Broken or Destroyed When Used Installation Accuracy of Each Component Component Resistance in its Original Position. | Agree |
|     |                                             | Made of Safe Materials (Not Sharp)            | Very Agree |
|     |                                             | Safe Construction for Students (Not Easy to Collapse) | Very Agree |
|     |                                             | The use of tools does not require special treatment (wearing a mask or gloves). | Very Agree |
|     |                                             | No Effect of Harmful Chemicals (Non-Flammable, Non-Irritating). | Very Agree |

3.2.4. Assessment by students
Aspects assessed by class XII MIA students included learning motivation and understanding of the concept of renewable energy sources using teaching aids, the operation and performance of teaching aids, and the quality of teaching aids. The results of the assessment by students are presented in Table 9. From the data of the questionnaire analysis, it can be seen that the average students' responses were "Very agree" with a percentage above 80% for all aspects assessed. In other words, class XII MIA students of SMA Negeri 2 Sigi responded very well to the existence of a heat energy conversion device into electrical energy as a teaching aid for physics learning designed by researchers.
Table 9. Assessment Results by Class XII MIA Students

| No. | Criteria                                                                 | Response Criteria                                                                 | Result   |
|-----|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------|
| 1   | Motivation to learn and understand the concept of renewable energy sources with teaching aids | It is easier for me to understand the concept of physics in renewable energy sources with the presence of teaching aids. My enthusiasm for learning Physics has increased with the use of teaching aids as a medium of learning. I enjoy learning Physics with props. I am more active in learning with teaching aids. I collaborate with friends when learning using props. The teaching aids can increase my knowledge about the application of physics. The existence of teaching aids in learning made me interested in trying and making teaching aids as exemplified. | Very agree Very agree Very agree Very agree Very agree |
| 2   | Operation and performance of props                                        | The props are easy to operate. Props work well when used. Props are suitable for use for class XII students | Agree    |
| 3   | Props quality                                                             | The teaching aids helped me to gain an understanding of the concept of renewable energy sources. Teaching aids can present the concept of renewable energy sources. | Very agree |

Based on the observation results of heat energy converted into electrical energy using a device with a thermoelectric cooler 12706 as the base material, it follows the theory that the greater the temperature difference between the two sides, the greater the electrical energy produced. From the observations on four experiments using 1, 2, 3, and 4 candles as a source of heat energy, the amount of heat energy affects the amount of electrical energy produced. From the graph of the observations, it can be seen that the voltage generated by the heat energy conversion device into electrical energy is proportional to the temperature difference between the two junctions. The results obtained that the average potential difference in degrees Celsius was 0,272 V/°C. While the results obtained for the average electric current per degree Celsius was 1,44 x 10⁻⁴ A/°C, and the amount of electric power obtained per degree Celsius was 1,68 x 10⁻³ Watt/°C.

4. Conclusion
Based on the results of data analysis and discussion, it can be concluded that the device for converting heat energy into electrical energy as a teaching aid for physics meets the Very Good criteria and is suitable for use. The produced energy converter specifies the relationship between the temperature difference of the two sides and the increase in potential difference and electric current. The average value for the potential difference per degree Celsius was equal to 0,272 V/°C, the electric current per degree Celsius was 1,44 x 10⁻⁴ A/°C, and the magnitude of the electric power per degree Celsius was 1,68 x 10⁻³ Watt/°C.
Acknowledgement
We highly acknowledge the support of the Program Kompetisi Kampus Merdeka (PK-KM) Grant of the Education, Culture, Research, and Technology of the Ministry of the Republic of Indonesia, with funding identity: 119/E1/KM.05.03/2021.

References
[1] Saehana S, Ali M and Supriyatman S 2019 T J. Pendidik. IPA Indones. 8 241–246
[2] Franklin S and Peat M 2005 Int. J. Contin. Eng. Educ. Life Long Learn. 15 67–78
[3] Hani U S 2017 Pengembangan media pembelajaran sebagai alat peraga penerapan konsep hukum pascal untuk peserta didik kelas viii smp
[4] Lestari L P 2006 Keefektifan pembelajaran dengan penggunaan alat peraga dan lembar kerja siswa (lks) terhadap hasil belajar matematika dalam pokok bahasan bangun segiempat pada siswa kelas vii semester 2 di smp muhammadiyah margasari kabupaten tegal tahun pelajaran 2005/2 (Universitas Negeri Semarang)
[5] Lee J S 2014 J. Educ. Res. 107 177–185
[6] Zacharia Z C 2007 J. Comput. Assist. Learn. 23 120–132
[7] Izzah A and Saehana S 2021 J. Phys. Conf. Ser. 1760
[8] Rohman A, Komang Werdhiana I and Saehana S 2021 J. Phys. Conf. Ser. 1760
[9] Ajredini F, Izairi N and Zajkov O 2017 Eur. J. Phys. Educ. 5 59–70
[10] Baser M and Durmus S 2010 Eurasia J. Math. Sci. Technol. Educ. 6 47–61
[11] Farrokhnia M R and Esmailpour A 2010 Procedia-Social Behav. Sci. 2 5474–5482
[12] Sugiyono 2012 Metode Penelitian Pendidikan (Bandung: Alfabeta)