

Development of a Renewable Energy Model Based on Discovery Learning to Improve Students' Critical Thinking Skills

Syifa Fauzia¹, Erina Hertanti^{1,2} and Fuji Hernawati Kusumah¹

¹ Physics Education UIN Syarif Hidayatullah Jakarta, Jl. Ir. H. Juanda No.95, Ciputat, South Tangerang, Indonesia

²E-mail: erina.hertanti@uinjkt.ac.id

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Abstract. The low critical thinking skills of students in renewable energy learning and the limited availability of teaching aids that integrate various renewable energy sources are the background of this research. This research aims to develop a renewable energy model based on discovery learning to improve students' critical thinking skills. This research uses a development research model consisting of four stages: preliminary research, prototyping stage, formative evaluation and summative evaluation. This research was conducted at MA Al-Khairiyah North Jakarta involving experts, teachers, and grade 10 students. The model integrates two renewable energy sources (solar and wind) in one system equipped with student worksheets based on discovery learning. Data were collected through expert validation questionnaires, student and teacher response questionnaires, and critical thinking ability tests. The results showed that the model met the criteria of feasibility, practicality, and effectiveness. Based on validation by media experts and subject matter experts, the model obtained percentage scores of 83.24% and 86%, respectively, with an average of 84.62%, included in the very feasible category. The practicality assessment showed a score of 93.75% from students and 87.5% from teachers, both categorized as very practical. The effectiveness aspect received a score of 90.6% from teachers, categorized as very effective. Students' critical thinking skills showed consistent improvement across all stages of the evaluation with n-gain values ranging from 0.30 to 0.46, included in the moderate category. In conclusion, the renewable energy model based on discovery learning has proven effective in helping students understand the concept of renewable energy and improve their critical thinking skills through active learning experiences and observations.

Keywords: renewable energy, discovery learning, critical thinking

1. Introduction

Renewable energy is one of the teaching materials in the high school physics curriculum. Renewable energy material covers various fundamental concepts such as work, energy, power, energy efficiency, the law of conservation of energy, energy conversion, renewable and non-renewable energy [1]. The process of learning renewable energy is often less interesting and tends to be boring for students [2]. Therefore, teachers need to adapt their teaching methods to make them more hands-on, using practical exercises or demonstrations that clearly show how renewable energy sources work [3]. This research aims to improve the renewable energy learning process to be more interesting in order to motivate students in achieving learning objectives through the use of teaching aids.

In renewable energy, a number of teaching aids have been developed. One such development was carried out by Delima et al. (2020) [4]. The teaching aid developed by Delima et al. (2020) is a solar cell-based teaching aid operating on the Arduino Uno microcontroller. However, this study has a weakness, namely the limited renewable energy sources, which only provide examples of solar energy (photovoltaic). According to Salmon & Bañares-Alcántar (2022), renewable energy can be categorized as zero-carbon energy, self-producible, cost-effective, and can be stored for long periods as an

alternative energy [5]. In addition to adding another renewable energy source, this teaching aid is designed as a model featuring two miniature buildings using different renewable energy sources. The renewable energy model in this study was used to enhance critical thinking skills.

Critical thinking can be defined as a mathematical, logical, and objective approach to making decisions or solving existing problems. This is a cognitive process that involves analyzing and evaluating the information obtained. Critical thinking is active and reflects the motivation and desire to find solutions and understand an issue in depth. Indirectly, critical thinking also includes evaluating the assumptions contained in information heard or read, as well as in an individual's thought processes when writing, solving problems, and making decisions [6].

John Dewey (1859-1952) defined critical thinking as the active and deliberate process of developing beliefs or knowledge. In this process, individuals analyze and seek arguments to support their conclusions. In general, critical thinking can be understood as an attitude that is not passive and does not accept information directly without filtering it. Conversely, individuals who accept information without analyzing it tend not to be considered critical thinkers [7]. According to Fahrudin Faiz (2012), critical thinking skills can be facilitated through learning that invites students to undertake discovery learning [8]. Therefore, the model was created based on discovery learning.

Oemar Hamalik [9] states that discovery learning is learning that emphasizes the development of students' intellectual abilities in solving problems, so that students can find concepts that can be applied in real life [10]. The discovery learning model not only focuses on the discovery process but also plays a role in improving students' critical thinking skills. This learning model optimizes students' potential to identify and acquire systematic, critical, logical, and analytical information, enabling them to formulate their own discoveries with confidence [11]. Through the discovery learning approach, students are expected to be able to explore and understand learning concepts in depth through direct experience. Based on the principles of discovery learning, this study attempts to develop the renewable energy teaching aid by adding another renewable energy source, namely wind energy, which originates naturally. This addition aims to identify the most environmentally friendly energy sources. By using this teaching aid, students can explore and make their own discoveries regarding the characteristics of various renewable energy sources, thus making the learning process more meaningful and in line with the concept of discovery learning.

2. Method

The development of this research refers to the development research model proposed by Jan Van Den Akker. The stages in this model consist of four main parts: Preliminary Research, Prototyping Stage, Summative Evaluation, and Systematic Reflection and Documentation [12]. The implementation of this research was limited to the summative evaluation stage. These stages are explained in Figure 1.

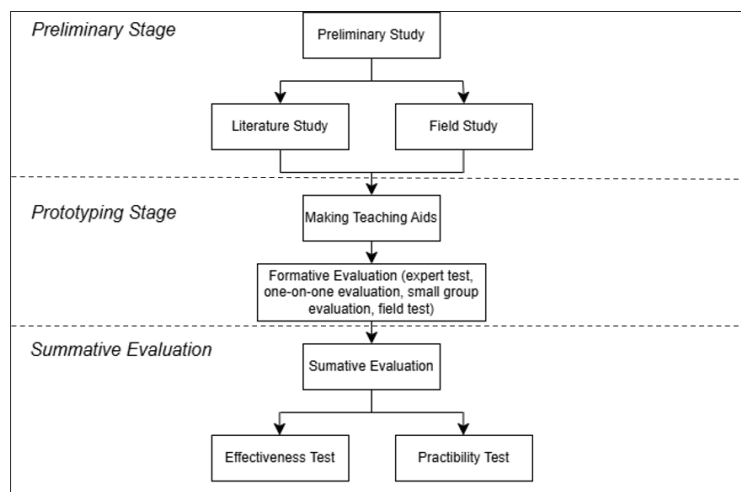


Figure 1. Stages of the development research model proposed by Jan Van Den Akker [13].

The preliminary stage involves gathering initial information related to the research problem through literature and field studies. The literature study focused on critical thinking skills and the weaknesses of previously developed teaching aids. The field study identified needs, actual school conditions, and learning constraints related to renewable energy materials [14].

The prototype stage is divided into three stages. First, the design guidelines for a renewable energy mockup as an initial design, referring to the results of the literature and the weaknesses of previous media. Second, the optimization of the design prototype, which includes designing the circuit schematic, the assembly process of various components, and testing. Third, the formative evaluation consists of expert validation tests, one-on-one evaluations, small group tests, and field tests.

The summative evaluation stage aims to measure the effectiveness and practicality of the renewable energy model. Effectiveness is determined through pretests and posttests to observe the development of students' critical thinking skills, while practicality is assessed using a response questionnaire completed by the teacher and students.

This research was conducted at MA Al-Khairiyah North Jakarta, with experimental subjects consisting of experts, students and teachers as described in Table 1.

Table 1. Experimental subjects.

Stage	Subject
Expert Review	Physics Lecturers from UIN Syarif Hidayatullah Jakarta (3 media experts, 3 physics content experts)
One-to-one Evaluation	3 students from 10th grade at MA Al Khairiyah North Jakarta
Small Group Evaluation	12 students from class X of MA Al Khairiyah North Jakarta
Field Test	15 students from 10th grade at MA Al Khairiyah North Jakarta
Summative Evaluation	Physics Teacher at MA Al-Khairiyah North Jakarta (2 People) 10th Grade Students from Al-Khairiyah Islamic High School, North Jakarta (20 People)

The instruments in this study consist of test and non-test instruments. The test instruments are pretest and posttest questions compiled based on the aspects of critical thinking skills according to Facione (2015) [15]. The test instrument aims to assess the effectiveness of the renewable energy model in improving students' critical thinking skills, with indicators including interpretation, analysis, inference, explanation, and evaluation. Meanwhile, the non-test instruments include interviews, questionnaires for media and material expert testing, and questionnaires for student and teacher responses.

The expert test questionnaire, student and teacher response questionnaires were analyzed using a quantitative method with a Likert scale and 4 score categories as shown in Table 2.

Table 2. Likert scale criteria [16].

Score	Category
4	Very good
3	Good
2	Not good
1	Very not good

The average score of each item of the expert test questionnaire statement, student and teacher responses was calculated using the following formula:

$$Results = \frac{\text{total score obtained}}{\text{ideal score}} \times 100 \quad (1)$$

After obtaining the results from the formula above, the feasibility and practicality can then be determined. The feasibility was assessed based on the validation results from experts and analyzed according to the criteria established by Ernawati (2017), as shown in Table 3.

Table 3. Eligibility criteria [17].

Score (%)	Eligibility Category
< 21 %	Very unsuitable
21 – 40 %	Not suitable
41 – 60 %	Quite suitable
61 – 80%	Suitable
81 – 100 %	Very suitable

Practicality was measured using a questionnaire filled out by teachers and students, then analyzed using the criteria proposed by Ardy Irawan (2021) as shown in Table 4.

Table 4. Practicality Criteria [18].

Score (%)	Practicality Category
< 20 %	Very impractical
21 – 40 %	Practical
41 – 60 %	Quite practical
61 – 80%	Practical
81 – 100 %	Very practical

The effectiveness of the teaching aids is measured by comparing the pretest and posttest results using the N-gain value. The N-gain value is used as an indicator to assess the effectiveness of the developed mock-up. The formula used to calculate N-gain is as follows:

$$N - gain = \frac{Posttest - Pretest}{Maximum\ score - Pretest} \quad (2)$$

This formula can also be written in percentage form:

$$N - gain\% = \frac{Posttest - Pretest}{Maximum\ score - Pretest} \times 100\% \quad (3)$$

The N-gain analysis was conducted using Microsoft Excel by entering the students' scores, processing the data, and examining the results after processing. The N-gain score criteria are shown in Table 5.

Table 5. N-gain Score Criteria [19].

Value Range	Category
> 0.7	High
0.3 > 0.7	Medium
< 0.3	Low

The N-gain criteria in percentage for determining the effectiveness level are shown in **Table 6.**

Table 6. N-gain Criteria in Percentage [19].

Percentage (100%)	Interpretation
< 40	Not Effective
40 – 55	Less Effective
56 -75	Quite Effective
> 76	Effective

3. Results and Discussion

This research produced a renewable energy model based on discovery learning. The model integrates solar and wind energy sources as a learning medium. The development goal is to improve students' critical thinking skills. The development process follows the Jan Van den Akker model, which includes

the Preliminary Research stage, the Prototyping Stage, and the Summative Evaluation [13]. The stage descriptions can be detailed as follows:

3.1. Preliminary Research

The literature study stage shows that teaching aids play an important role in changing abstract concepts in physics learning [20], especially when integrated with the discovery learning model which encourages students to actively discover concepts independently [21]. Research by Gumelar et al. (2018) [22] proved the effectiveness of renewable energy models in improving students' critical thinking skills, but research by Delima et al. (2020) [4] limited to solar energy. Therefore, this study developed a renewable energy model that integrates solar and wind energy to develop critical thinking skills. This approach aligns with the findings of Prince and Felder (2006) [23] which shows that active learning based on discovery learning produces deeper understanding than direct learning. Thus, the integration of renewable energy models with discovery learning is consistent with international empirical evidence regarding its effectiveness in developing critical thinking skills.

3.2. Prototyping Stage

Prototype stage, the activity begins with designing a renewable energy model. This process begins with the creation of a mock-up design that considers the shortcomings. The model is designed with two main energy sources: solar panels and wind turbines. The design of the renewable energy model can be seen in **Figure 2**.



Figure 2. Renewable energy mockup design.

The next stage was optimizing the model to improve performance, efficiency, and educational value in learning. Optimization included adjusting the position and angle of the solar panels to maximize sunlight absorption, as well as improving the wind turbine design for stability and efficiency. Furthermore, the quality of the electrical circuit was improved by using better conductor cables to minimize energy loss. From a learning perspective, optimization also included the development of discovery learning-based Student Worksheets (LKPD) and tool usage guides, so students could more easily understand the energy conversion process and conduct independent observations.

3.3. Formative Evaluation

Formative evaluation is carried out referring to the Tessmer model [24] This included expert validation, one-on-one evaluation, small group evaluation, and field testing. Expert validation involved three media

experts and three material experts to test the model's suitability for facilitating learning [25]. Expert validation results showed the feasibility of the model with a percentage of 83.24% (media experts) and 86% (material experts), resulting in an average of 84.62% (very feasible category). This value is higher than the previous research [26] which achieved 82% feasibility for the renewable energy mockup. The concept suitability aspect achieved a perfect score (100%), indicating that the mockup accurately represents the working principles of renewable energy. The accuracy (58.75%) and efficiency (78.33%) aspects were the focus of improvement based on expert input.

A one-on-one evaluation with three students resulted in a feasibility score of 89.81% (very feasibility), an increase compared to the initial development stage. A small group evaluation (12 students) showed a feasibility score of 86.20%, with technical quality as the strongest aspect (93.75%). The pretest-posttest results at this stage recorded an increase in the average score from 74.03 to 87.78 with an n-gain of 0.46 (moderate category). This n-gain value is higher than the research results [27] which obtained an n-gain of 0.38 in the development of physics learning media.

Field testing (15 students) showed an increase in feasibility to 95.19%, indicating successful improvements based on feedback from the previous stage. The n-gain value at this stage is 0.30 (moderate category), slightly lower than the small group evaluation but still showing adequate effectiveness. This difference can be explained by the greater heterogeneity of student abilities, which is more varied in larger samples, consistent with the findings [28] which states that the n-gain in the medium category remains effective if accompanied by a significant improvement in learning outcomes.

3.4. *Summative Evaluation*

At the summative evaluation stage, assessing practicality by students (93.75%) and teachers (87.5%) indicated a very practical category, exceeding the minimum practicality standard of 76%. The effectiveness aspect received a rating of 90.6% from teachers. The pretest and posttest results in the summative evaluation showed an n-gain of 0.40, confirming the consistency of the model's effectiveness across various evaluation stages.

The renewable energy model based on discovery learning shows a positive impact on students' critical thinking skills. Models not only serve as demonstration tools, but also as a means of learning experiences that require students to observe, analyze, and draw conclusions. This finding aligns with [29] who stated that critical thinking develops thru student involvement in evidence-based decision-making. Thus, the developed model is feasible, practical, and effective. However, limitations still exist in the scope of renewable energy, which is not yet fully comprehensive. Therefore, although the model has been effectively used in learning, further development is still needed to improve the product for various physics learning contexts.

4. Conclusion

Based on the analysis of the results and discussion, it can be concluded that this research produced a learning media product in the form of a renewable energy model with a discovery learning approach. The development of this model is aimed at improving students' critical thinking skills in understanding renewable energy materials. The evaluation results show that the model produced is categorized as valid, practical, and effective for use as a physics learning medium. Future researchers are advised to develop a prototype design from an analog system to a digital one using Arduino Uno with current, voltage, and wind speed measurement sensors to improve data precision and accuracy. The renewable energy model is expected to optimize effectiveness in enhancing students' critical thinking skills thru design improvements and the integration of more renewable energy sources.

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References

- [1] Rizki I A, Hariyono E, Suprpto N, Dawana I R and Shobah N 2024 Renewable Energy Learning Project in Physics Classroom: Achieving Education for Sustainable Development *TEM Journal* **13** 1452
- [2] Hulwah H 2024 *Pengaruh Pembelajaran Pjbl-Stem Terhadap Kemampuan Berpikir Sistem Siswa Pada Materi Energi Alternatif* (UIN Syarif Hidayatullah Jakarta)
- [3] Hamidun, Satriawan M and Subhan M 2022 Pembelajaran Fisika Tentang “ Sumber Energi Terbarukan ” Berbantuan Prototipe Konverter Sistem Reduksi Ganda Meningkatkan Hasil Belajar Siswa *Navigation Physics : Journal of Physics Education* **4** 56–62
- [4] Delima M E, Mayub A and Nursa’adah E 2020 Pengembangan Alat Peraga Energi Terbarukan Berbasis Solar Cell pada Pembelajaran IPA *Jurnal Pendidikan* **13** 284–90
- [5] Salmon N and Bañares-Alcántara R 2022 A global, spatially granular techno-economic analysis of offshore green ammonia production *Journal of Cleaner Production* **367** 133045
- [6] Putri A R 2020 Analisis Kemampuan Berpikir Kritis Mahasiswa (Studi Kasus pada Mahasiswa Pendidikan Akuntansi) *Repository Universitas Islam Riau* 8–15
- [7] Sihotang K 2019 *Berpikir Kritis Kecakapan Hidup Di Era Digital (Edisi Revisi)* (Daerah Istimewa Yogyakarta: PT Kanisius)
- [8] Rakhmawati R A and Mawardi M 2021 Model Pembelajaran Discovery Learning Untuk Meningkatkan Keterampilan Berpikir Kritis Siswa Kelas 5 SD *Jurnal Ilmiah Profesi Pendidikan* **6** 139–44
- [9] Oemar H 2009 *Pembelajaran Fisika: Teori dan Praktik* (Jakarta: Bumi Aksara)
- [10] Yadi H F, Neviyarni and Nirwana H 2022 Discovery Learning Sebagai Teori Belajar Populer Lanjutan *Jurnal Literasi Pendidikan* **1** 234–45
- [11] Laeni S, Zulkarnaen Z and Efwinda S 2022 Model Discovery Learning terhadap Kemampuan Berpikir Kritis Siswa SMA Negeri 13 Samarinda Materi Impuls dan Momentum *Jurnal Literasi Pendidikan Fisika (JLPF)* **3** 105–15
- [12] van den Akker J J H, Gravemeijer K, McKenney S and Nieveen N 2006 *Educational design research* vol 2 (Routledge London)
- [13] Akker J Van Den, Gravemeijer K, Mckenney S and Nieveen N 2006 Design research from a technology perspective. Chapter in *Educational Design Research* 1–177
- [14] Gall M D, Gall J P and Borg W R 2003 *Educational Research: An Introduction* (Allyn and Bacon)
- [15] Peter A. Facione 2011 Critical Thinking : What It Is and Why It Counts *Insight assessment* 1–28
- [16] Purwanti S and Anggraini Putri R Z 2021 Pengembangan Modul Berbasis Hots Pada Tema 6 Materi Membandingkan Siklus Makhluk Hidup Kelas Iv Sekolah Dasar *Elementary School: Jurnal Pendidikan dan Pembelajaran ke-SD-an* **8** 155–60
- [17] Ernawati I and Sukardiyono T 2017 Uji Kelayakan Media Pembelajaran Interaktif Pada Mata Pelajaran Administrasi Server, Elinvo (Electronics, Informatics, and Vocational Education) **2** 204–10
- [18] Putro P C and Setyadi D 2022 Pengembangan Komik Petualangan Zahlen Sebagai Media Pembelajaran Matematika Pada Materi Bangun Ruang Sisi Datar *Mosharafa: Jurnal Pendidikan Matematika* **11** 131-142
- [19] Sukarelawan Moh I, Indratno T K and Ayu S M 2024 *N-Gain vs Stacking*
- [20] Fitriana R, Amaliyah A and Unaenah E 2024 Pengaruh Media Konkret Terhadap Hasil Belajar Matematika Siswa Kelas 2 SD Negeri Bojong 3 Kota Tangerang *Jurnal Imiah Wahana Pendidikan* **10** 776–81
- [21] Hosnan M 2014 *Pendekatan saintifik dan kontekstual dalam pembelajaran abad 21: kunci sukses implementasi kurikulum 2013* (Ghalia Indonesia)
- [22] Gumelar B W, Widiastuti I and Wijayanto D S 2018 Pembelajaran Energi Terbarukan Untuk Sekolah Dasar Studi Kasus Di Kabupaten Klaten *Jurnal Ilmiah Pendidikan Teknik Kejuruan* **12** 56–64
- [23] Prince M J and Felder R M 2006 To state a theorem and then to show examples of it is literally to teach backwards. *Learning* **95** 123–38

- [24] Tessmer M 1993 *Planning and Conducting Formative Evaluations: Improving the Quality of Education and Training* (Kogan Page)
- [25] Fahrudin A 2018 Universitas Papua Application and Its Effect on Elasticity Learning Achievement *Kasuari : Physics Education Journal (KPEJ) Universitas Papua* **1** 22–33
- [26] Hartini S, Dewantara D and Mahtari S 2018 Pengembangan Alat Peraga Fisika Energi Melalui Perkuliahan Berbasis Project Based Learning *Vidya Karya* **33** 42
- [27] Alatas F and Fachrunisa Z 2019 an Effective of Pogil With Virtual Laboratory in Improving Science Process Skills and Attitudes: Simple Harmonic Motion Concept *Edusains* **10** 327–34
- [28] Zainuddin Z, Mastuang M, Misbah M, Melisa M, Ramadhani F D, Rianti D and Rusmawati I 2021 The Effectiveness of Fluid Physics Practicum Module Based On Wetland Environment to Train Science Process Skills *Kasuari: Physics Education Journal (KPEJ)* **3** 76–84
- [29] Gonzalez H C, Hsiao E L, Dees D C, Noviello S R and Gerber B L 2022 Promoting critical thinking through an evidence-based skills fair intervention *Journal of Research in Innovative Teaching & Learning* **15** 41-54