International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 16, No. 3, September 2025, pp. 1457~1471
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v16.i3.pp1457-1471

Solar cell-based garden light automation for environmentally friendly technology learning

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Article Info

Article history:

Received Nov 29, 2024
Revised May 22, 2025
Accepted Jun 3, 2025

Keywords:

Automation
Environmentally
Friendly solar cell
Increase
Lights
Microcontroller

ABSTRACT

This research aims to: 1) Produce a prototype design for a solar cell-based automatic garden lighting system; 2) Determine the relationship between current, power, and voltage and light intensity; 3) Describe the feasibility of an environmentally friendly technology practicum guidebook; and 4) Describe teacher and student responses to the environmentally friendly technology practice guidebook. This research is R&D type Analysis, Design, Development, Implementation and Evaluation (ADDIE) Analysis, design, development, implementation and evaluation. The research sample used 44 class IX students at MTS Rahmatullah. According to students, aspects of teaching materials, aspects of content, and difficulty of teaching materials at school are inadequate at 84.25%, 80% and 82.5%. Student interest in environmentally friendly technology practicum guidebooks was 84.25%. The higher the light intensity, the higher the current, power, and voltage. Expert validation shows; the prototype of an automatic garden lighting system based on solar cells and a practical guidebook on environmentally friendly technology are very suitable for use (89.14% and 90.75%). The use of environmentally friendly technology practicum guidebooks increased students' critical thinking skills in the high category (N-Gain = 0.7937) and received responses from teachers and students in the "almost all" category (91.50% and 89.9%).

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1. INTRODUCTION

Electrical energy is a resource that contributes to world globalization [1]. 80% of Indonesia's energy needs are met using petroleum, and its use increases every year; therefore, alternative energy must be developed [2]-[5]. Indonesia's electrical energy consumption grows 3.46% per year, mostly using fossil energy. So that activities that use electricity reduce the availability of fossil energy sources. Therefore, alternative energy is needed so that dependence on fossil energy can be reduced. One alternative energy source that is abundant, easy to obtain, cheap, and environmentally friendly is sunlight. Indonesia receives sunlight throughout the year, but this energy has not been utilized optimally for energy needs [6]-[10]. Indonesia is located in the equatorial region and receives solar energy, which can be utilized by converting solar radiation into other forms of energy through solar cells [11], [12].

Solar energy is an environmentally friendly technology, a large energy supply, and a renewable energy source. The application of solar energy contributes to sustainable development because it provides energy needs, creates jobs, and improves environmental protection. The perspective of solar energy technology is structured in the application of the energy sector and provides a vision of future development in the energy sector [13]. Solar panels emit no pollution while producing electricity as a renewable energy source. However, solar panels are adversely affected by adhering dirt, so that the intensity of sunlight falling on the panels is reduced. This reduces the electrical output of energy produced by solar panels. Therefore, smart systems need to address dirt buildup on solar panels by considering efficiency, accuracy, complexity, and reliability. Overall, real-time monitoring and cleaning of solar panels increases their output power with an integrated intelligent system [14]. Solar cells absorb sunlight to release electrons from silicon atoms and move forward to form an electrical circuit so that electrical energy can be generated. Solar energy can be directly converted into electrical energy via solar cells [15]-[17]. Solar energy can be used as an alternative energy through solar cells; this is the best solution to the problem of reduced electricity supply from the State Electricity Company (PLN). PLN cutting off electricity at night causes problems with lighting, for example, in garden locations; therefore, it is necessary to provide garden lights using sunlight. Solar cells can be used to store electrical energy in batteries to be used automatically as lighting at night without having to use electrical energy from PLN. Therefore, it would be better to use an automatic system for garden lights using solar cells that can be directly distributed to the load or stored in batteries before use.

Figure 1 explains that photons emitted by the sun with mc2 energy hit the silicon semiconductor of the solar cell, releasing electrons from its structure. These free electrons cause atoms to lose electrons, resulting in positively charged "holes". Negative free electrons fill the part of the semiconductor that functions as an N-type semiconductor. The part of the semiconductor that has positive holes functions as a P-type semiconductor. The PN Junction formed at the junction of the P-type and N-type produces energy that is able to push the electrons and holes to move in opposite directions, thereby producing an electric current.

In line with the description above, there are two studies entitled: Sustainable renewable energy does not focus on the use of solar cells in prototyping related to solar cells for automated garden lighting systems [18]-[20]. The potential and role of solar power plants (PLTS) can function as an alternative energy [21]. Both of these studies used diesel fuel, did not use the ATMEGA328 microcontroller, so they were not used automatically. In other research, solar cells were used, but did not use light sensors, so they did not detect sunlight automatically and focused on measuring output power [22]-[24]. Preview study [25], [26], the similarities are only in the lights used, but the ATMEGA microcontroller used is a different type. Yossi's research uses an ATMEGA16 microcontroller, while this research uses an ATMEGA328 microcontroller and uses a light sensor and measure power, voltage, and current. Other research concludes that solar cells as a renewable energy can be used to create lighting prototypes [27]-[31].

Based on the description above, the author needs to conduct research on Environmentally Friendly Solar Cell Technology for Automatic Garden Lighting Systems. The problem in this research is formulated as: i) How to design a prototype of a solar cell based automatic garden lighting system; ii) What is the relationship between voltage, electric current and power and light intensity in a prototype of a solar cell based automatic garden lighting system; iii) What is the feasibility of a practical guidebook on environmentally friendly technology for a solar cell based automatic garden lighting system; and iv) How are students' critical thinking abilities after learning using an environmentally friendly technology practice guidebook.

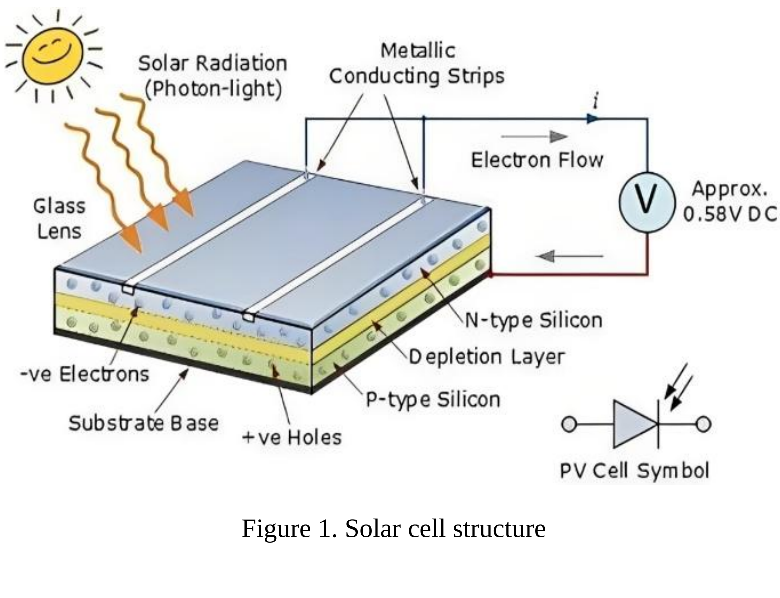

Figure 1. Solar cell structure

2. THE PROPOSED METHOD/ALGORITHM/PROCEDURE SPECIFICALLY DESIGNED (OPTIONAL)

In order to find a solution to the problem, the objectives of this research were determined, namely: i) to describe the design of a prototype of an automatic system for solar cell-based garden lights, ii) to describe the physical variables of voltage, electric current and power based on light intensity on a prototype of an automatic system for solar cell-based garden lights, and iii) describe the suitability of the environmentally friendly technology practicum guidebook, iv) describe students' critical thinking abilities after learning using the environmentally friendly technology practicum guidebook. The research objectives can be achieved through the following completion algorithm; i) Create a prototype design for an automatic garden lighting system using solar cells; ii) Test and calculate the physical variables of voltage, electric current and power based on light intensity on a prototype automatic solar cell garden lighting system; iii) Test the feasibility of a friendly technology practical guidebook. The automatic environmental system for solar cell garden lights; and iv) Tests students' critical thinking skills after learning using an environmentally friendly technology practical guidebook.

3. METHOD

The ADDIE research and development model; Analysis, Design, Development, Implementation and Evaluation was used in this research [32]. Meanwhile, 44 students in class IX MTS Rahmatullah for the 2023/2024 academic year were used as the research population. Sampling used purposive sampling technique. Instrument tests and tests were carried out on 22 class IX A students.

3.1. Research stages

3.1.1. Needs analysis

The analysis stage aims to determine the suitability of core competencies and basic competencies in the curriculum with the material developed so that students are able to understand alternative electrical energy. Aspects of teaching materials, aspects of content, and aspects of difficulty are inadequate, so students show high interest when given a science practice guidebook. This analysis includes analysis of core competencies, basic competencies, learning materials, needs for teaching materials and analysis of product needs for prototype solar cell automatic garden lights.

3.1.2. Design

Based on the analysis above, a prototype design for an automatic series and parallel solar cell garden lighting system was carried out. To build a solar cell-based garden light, you need materials/tools as shown in Table 1. Meanwhile, the solar cell design and circuit block diagram look like Figures 2 and 3.

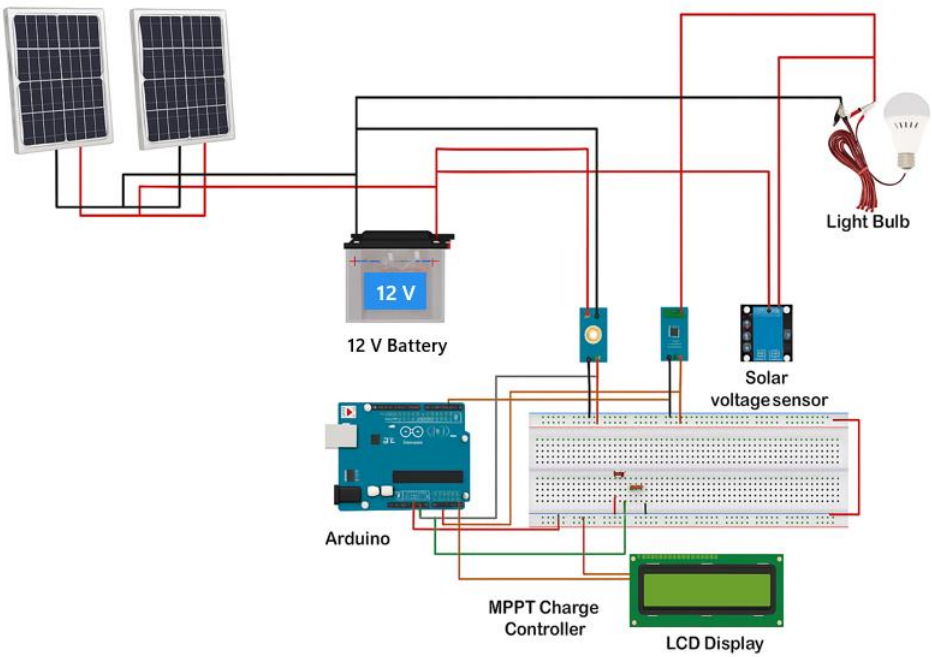

Figure 2. Solar cell design

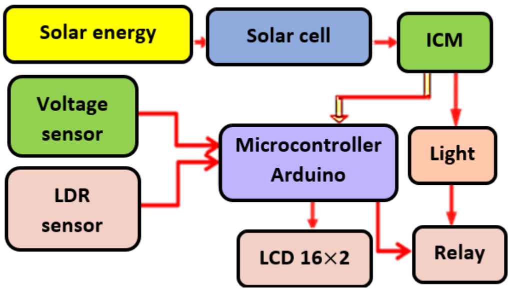

Figure 3. Circuit block diagram

Table 1. Requirements for solar cell-based garden lights

Software component	Specification
LDR sensor	GL5516 maximum 5 Volt LDR sensor
DC Voltage sensor	Input voltage 25 Volts
Arduino microcontroller	ATMega 328 with operating Voltage 5 volts, Flash memory 32 KB
LCD	16×2 or 1602
Relays	Model SRD-05VDC-SL-C (173)
Solar cells	5-volt polycrystalline-type solar cell
Hardware components	Specification
Laptops	Almost all types of laptops can be used for programming
Scissors	Joyko SHARP Scissors SC-828 SC-838 SC-
Paper	848 small large scissor paper - SS-5
Jumper cables	Jumper Cable 10 Cm male to male/female to female/male to female
Light	Hannochs' 50-Watt LED lamp with a voltage of 220-240 volts.
Accu	Accu GSJ Premium KIT GM5Z-3B/GT6A/YB5L wet battery, 12-volt, 5 amperes

The design of the practical guidebook for the use of solar cells is as shown in Figure 4. This research uses instruments in the form of; student response questionnaire on current learning, validation sheet for prototype of automatic garden lighting system, validation questionnaire for feasibility of practical guidebook and test to measure students' critical thinking abilities.

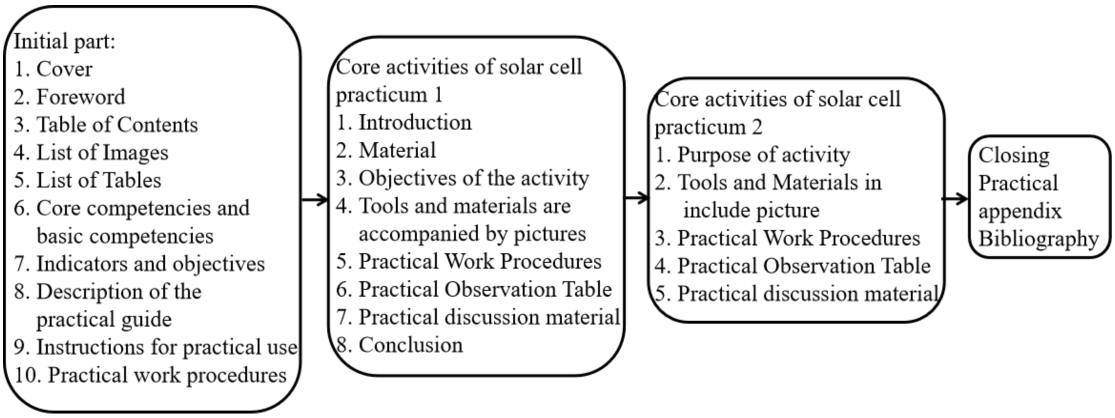

Figure 4. Design of a practical guidebook

3.1.3. Development

Based on the above analysis, a prototype design for an automatic lighting system was carried out. At this stage, a validation test was carried out on a prototype product for a solar cell-based automatic garden lighting system. The validity test of the environmentally friendly technology practice guidebook was carried out by three media expert lecturers and one science teacher using the Aiken validation index, as in (1).

$$V = \frac{\sum(r - Io)}{[n(c-1)]} \quad (1)$$

The formula above is used to determine the validity of the environmentally friendly technology practice guidebook. The quantities in the formula each have meaning; The number given by the assessor = r, the lowest validity assessment score = Io, the highest validity assessment score = c and the number of assessors = n [33]. Next, a validation test was carried out using the instrument test using a one-group pretest-post-test design.

3.1.4. Implementation

Quasi-experiments on class IX samples at MTS were used for product implementation. The pre-test to determine students' initial abilities and the post-test to see students' abilities after learning using the Environmentally Friendly Technology Practicum Guidebook were carried out to measure students' critical thinking abilities in aspects of context, content, and competency. Questionnaires and observation sheets are used to assess the dimensions of students' scientific attitudes. The checklist observation sheet consists of 20 questions, filled in by students and observers, while the questionnaire uses a Likert scale in the form of an attitude scale, which includes the range of strongly disagree, disagree, agree, and strongly agree. Table 2 is an implementation design with the following meanings: Z1 = Student needs analysis questionnaire, Z2 = validation of practicum guidebook, Z3 = student needs analysis, Z4 = teacher and student responses.

Table 2. Implementation design

Treatment	Pretest	Post test	Questionnaire				
X	Y1	Y2	Z1	Z2	Z3	Z4	Z1

3.2. Data collection techniques

An essay test of 8 questions is used to measure students' critical thinking abilities in the aspects of content, context, and competency. A series of questions to measure the knowledge, skills, intelligence, ability, or talent of a person or group is called a test, carried out as a pretest and posttest. Meanwhile, data collection techniques for validating practical manuals, analyzing student needs, teacher, and student responses use questionnaires. Giving a series of questions or written statements to respondents to answer is a data collection technique called a questionnaire. Meanwhile, the sheet for observers to fill in during learning activities to determine students' scientific attitudes is called an observation sheet. So that the data required at each stage can be obtained, instruments are needed as shown in Table 3.

Table 3. Research instruments

No	Step	Instrument type
1	Analysis	1. Needs analysis questionnaire and interview guide
		2. Table of KI, KD and indicators
		3. Design analysis of automatic garden lights
2	Design	4. Preparation of critical thinking learning steps
3	Development	5. Validation sheet for a prototype solar cell-based garden lighting system
		6. Validation sheet for environmentally friendly technology practicum guidebook
		7. Test instrument validation sheet
4	Implementation	8. Pretest and post-test question sheets
		9. Response questionnaire for environmentally friendly technology practicum guidebook

3.3. Data analysis techniques

3.3.1. Data analysis techniques for prototype automatic garden lighting systems

Before the prototype automatic garden lighting system is used in research, it is necessary to analyze all components of the existing automatic garden lighting system. The purpose of conducting system control testing analysis is to see the function of the tool and determine the possibility of the tool experiencing damage during the use process which will have an impact on the performance of the tool system. Test analysis of the automatic garden lighting system was carried out on the input and output parts of the system. Tools that need to be ensured to function properly in the input section, light dependent resistor (LDR) sensor, voltage sensor, and solar cell, while in the output section: current, voltage, power, and battery.

3.3.2. Data analysis of practical guide validation results

The appropriateness of teaching materials is based on 4 aspects, namely suitability of content, suitability of presentation, suitability of language, and suitability of graphics. Data analysis in the form of a questionnaire on the suitability of teaching materials was obtained in the form of a percentage of suitability of teaching materials, which was then interpreted according to the teaching material questionnaire grid. The teaching material questionnaire assessment uses a scale of 1 (very less) to 5 (very good) as in Table 4. The percentage results are obtained through calculations using (2).

$$(percentage) \ = \frac{\sum score\ obtained}{\sum maximun\ score} \times\ 100\% \quad (2)$$

Meanwhile, to determine the quality of suitability/appropriateness of the Practicum guidebook, the criteria as shown in Table 5 are used.

3.3.3. Needs questionnaire analysis

Analysis of the need for environmentally friendly technology, practical guidebooks in the form of open-ended question sheets to be filled in by students. The percentage calculation from the need questionnaire data obtained is processed using (3) [34].

$$(percentage) \ = \frac{\sum \text{total score}}{\sum \text{maxsimum score}} \times\ 100\% \quad (3)$$

Table 4. Questionnaire grid for teaching materials

No	Quality	Aspect					Score
		Contents	The graphic	Language	Presentation	Interest	
1	Very less						1
2	Not enough						2
3	Enough						3
4	Good						4
5	Very good						5

Table 5. Teaching material assessment qualifications (practicum guidebook)

Achievements (%)	Qualification	Information
81-100	Very worthy	No need for revision
61-80	Worthy	No need for revision
41-60	Decent enough	Revision
21-40	Not worth it	Revision
0-20	Very inadequate	

3.3.4. Test the validity of the questions

To determine the level of validity of the question items, the Pearson product-moment correlation formula is used with the question scores obtained, formulated as (4). The criteria for determining significance are by comparing the r-calculated and r-table values. If r-count > r-table, then we can conclude that the item is valid [35].

$$r_{xy} = \frac{N.\sum X.Y - (\sum X).(\sum Y)}{\sqrt{[(N\sum x^2) - (\sum x)^2][(N\sum Y^2) - (\sum Y)^2}} \quad (4)$$

3.3.5. Questionnaire reliability test for pretest and post-test questions

The formula used to test the reliability of the test instrument in this research uses the Alpha Cronbach formula, as (5).

$$(r_{11}) \ = (\frac{n}{n-1} \text{ x } (1 - \frac{\sum S_i{}^2}{S_i{}^2}) \quad (5)$$

Meanwhile, the criteria for interpreting the reliability of questions can be seen in Table 6.

3.3.5. Critical thinking analysis

The critical thinking test is given with 8 essay questions. The test for improving students' critical thinking was analyzed using the normalized N-gain concept based on pretest and post-test score data. The N-gain formula is as (6).

$$N_{gain} = \frac{(X_2 - X_1)}{(X_3 - X_1)} \quad (6)$$

X1 = pretest score, X2 = post-test score, X3 = maximum score, with the following criteria. To determine students' level of critical thinking, criteria are used as shown in Table 7.

3.3.6. Analysis of teacher and student responses

Student response sheets are processed with the percentage of respondents who agree or disagree. Regarding the statement items submitted with (7).

$$PTR(\%) = \frac{JR}{JSR} \times 100\% \quad (7)$$

PTR = Percentage of respondent responses, JR = Number of respondents, JSR = Number of all respondents. The data obtained is interpreted as in Table 8.

Table 6. Reliability interpretation

Value range	Category	Value range	Category
0.00 r11 ≤ 0.20	Very low	0.70 < r11 ≤ 0.90	Tall
0.20 < r11 ≤ 0.40	Low	0.90 < r11 ≤ 1.00	Very high
0.40 < r11 ≤ 0.70	Currently		

Table 7. Categories based on N-Gain score

No	N_{gain}	Category
1	≥ 0.70	High
2	0.30 – 0.70	Enough
3	0.30	Low

Table 8. Criteria for interpreting student response questionnaires

Percentage of number of respondents (%)	Criteria
PTR = 0	No one
0 < PTR < 25	Fraction
25 ≤ PTR ≤ 50	Almost partial
PTR = 50	Part
50 ≤ PTR ≤ 75	Most of the
75 ≤ PTR ≤ 100	Almost all

4. RESULTS AND DISCUSSION

Carrying out analysis, design, development, implementation, and evaluation (ADDIE) in this research includes the ADDIE Research and Development model [36]. The research population uses class IX students at MTS Rahmatullah for the 20232/2024 academic year, a total of 44 students. Sampling used a purposive sampling technique. The instrument test was carried out on 22 class IX A students, while test was carried out on 22 class IX A students.

4.1. Analysis

4.1.1. Analysis of core competencies, basic competencies, and learning materials

Analysis of core competencies and basic competencies in environmentally friendly technology material on the solar cell concept related to electrical circuits and in accordance with the 2013 curriculum syllabus. Based on the suitability of environmentally friendly technology material in basic competency 3.10, environmentally friendly technology processes and products for the sustainability of life 4.10. Presents work on simple technological processes and products that are environmentally friendly. The relationship between core competencies and basic competencies in the context of solar cells can be seen in Table 9.

Table 9 corresponds to the environmentally friendly technology material developed in the environmentally friendly technology practicum guidebook on the use of solar cells, which is found in Basic Competencies 3.10 and 4.10 on the theme of environmentally friendly technology. The core competencies and basic competencies above are in line with the material being developed; therefore, students can understand alternative electrical energy. In KD 3.10, it is hoped that students will be able to understand the importance of implementing environmentally friendly technology in everyday life. Based on Basic Competencies 3.10 and 4.10 above, indicators for the learning process can then be created.

Table 9. Core competencies and basic competencies related to solar cells

Core competencies	Basic competencies
KI 3: Understand factual, conceptual, and procedural knowledge based on curiosity about science, technology, art, and culture related to visible phenomena and events.	3.10 Analyze environmentally friendly technology processes and products for sustainable life
KI 4: Try, process, and present in the concrete domain (using, parsing, assembling, modifying, and creating) and the abstract domain (writing, reading, calculating, drawing, and composing) according to what is learned at school and other similar sources from a point of view/theory	4.10 Present work on simple technology processes and products that are environmentally friendly

4.1.2. Analysis of teaching material needs

Activities at this stage include observation, interviews, and questionnaires. Observations were made on science learning at MTs Rahmatullah. Interviews were conducted on September 29, 2024, with 2 science subject teachers using an interview guide. The needs analysis questionnaire used a needs questionnaire sheet given to 44 students at MTs Rahmatullah. The results of observations of science learning at MTs Rahmatullah show that some students use LKS and textbooks on a limited basis in the library. This is shown by the results of a questionnaire analyzing student needs based on teaching material aspects, content aspects, difficulty aspects, and interest aspects, as shown in Table 10.

After analyzing the existing teaching materials, the following results were obtained: According to students, the teaching material aspects, content aspects, and difficulty aspects are inadequate (No), respectively 84.25%, 80% and 82.5%. Because of this, the science practicum guidebook was offered and given, and after analysis, results were found which stated that the aspect of student interest in the science practicum guidebook was 84.25% (Yes).

Table 10. Results of the student needs questionnaire based on aspect groups

No	Rated aspect	Yes	No
1	Availability of teaching materials	20.00	80.00
2	Content suitability	17.83	82.17
3	Convenience	17.50	82.50
4	Interest in the guidebook offered	84.25	15.75

4.1.3. Analyze product needs for prototype automatic garden lights

The control system testing analysis aims to determine the functions of the tools and materials. In addition, this analysis ensures that there is no damage to the components during the prototype usage process. The details can be seen in Table 11.

4.1.4. Tool component testing

One of the important components in the automatic garden light prototype is a solar cell, which functions to convert light energy into electrical energy. Therefore, it is necessary to know the light intensity, light intensity value, power, voltage, and current produced, whether installed in series or parallel on the automatic garden light prototype. Component testing aims to determine whether the physical variables measured in each component can work according to the resulting measurements. In testing the analysis of this tool regarding solar light energy, which can be converted into electrical energy using solar cells, which are an alternative electrical energy, see Table 12. This research uses polycrystalline solar cells, which have an efficiency of 13%-16%. The results of the research show that solar cells have an average efficiency of 13% for series circuits and 14% for parallel circuits, see Table 13.

Table 11. Control system testing

Type of Arduino Uno Microcontroller ATMEGA 328	Component	Trials 1 to 5				
		1	2	3	4	5
Inputs	LDR sensor	√	√	√	√	√
	Voltage sensor	√	√	√	√	√
	Solar cells	√	√	√	√	√
Out put	Current	√	√	√	√	√
	Voltage	√	√	√	√	√
	Power	√	√	√	√	√

Table 12. Current, voltage, and power measurement data based on light intensity

No	Intensity light	Intensity value of light	Time	Series			Intensity value of light	Parallel		
				Current	Voltage	Power		Current	Voltage	Power
1	High	1271	13.00	0.23	36.5	8.40	471	0.55	18.25	10.04
	Low	658	09.00	0.11	24	2.64	318	0.22	12	2.64
2	High	471	13.00	0.28	36.5	10.22	471	0.56	18.25	10.22
	Low	318	09.00	0.06	32	1.92	318	0.12	16	1.92
3	High	1291	13.00	0.55	19.33	10.63	1295	0.54	19.30	10.42
	Low	957	09.00	0.12	17.24	2.07	957	0.12	17.2	2.06
4	High	1190	13.00	0.28	38.42	10.76	1190	0.56	1921	10.76
	Low	318	09.00	0.06	32	1.92	318	0.12	16	1.92
5	High	1198	13.00	0.55	38.98	21.40	1198	0.55	19.0	10.45
	Low	399	09.00	0.05	28.35	1.42	399	0.10	12.25	1.23

Table 13. Results of power readings from the solar monitoring system

Date	Yield (kWh)	Self-consumption (kWh)	Export (kWh)	Import (kWh)
15/08/2023	2,560	1,480	1,090	0.02
16/08/2023	2,160	1,230	929	0.01
18/08/2023	1,760	1,010	753	0.00
19/08/2023	2,100	1,210	887	0.01
21/08/2023	1,720	1,000	719	0.02
22/08/2023	1,500	867	630	0.01
25/08/2023	2,260	1,310	951	0.02
Total	14,060	8,107	5,959	0.09
Everage	2,009	1,158	851	0.01

4.2. Design

The analysis of teaching material needs and product prototype analysis of the solar cell-based automatic garden lighting system, which was carried out, was used to design a practical guidebook for environmentally friendly technology on the use of solar cells.

4.2.1. Design of a prototype of an automatic solar cell-based garden lighting system

The prototype of this automatic garden lighting system was prepared and assembled with the aim of providing open material so that the learning carried out can stimulate students to be more interest and easy for students to understand so that it can raise the level of critical thinking in students, therefore arranging the circuit and how to use it is made possible so that students can understand what is involved. prototype of the automatic garden lighting system. In accordance with the literature study that has been carried out, the tools and materials obtained to make a prototype of the automatic garden lighting system include: laptop, scissors, cables, printed circuit board (PCB) holes, LDR sensor, voltage sensor, ATMEGA 328 Microcontroller, liquid crystal display (LCD), Relays, solar cells, lights and batteries. For the preparation and assembly, based on the literature study, several processes were obtained, including the flow diagram for making a garden lighting system prototype, the prototype assembly flow diagram, the design of a prototype circuit for a garden automatic lighting system in series and parallel circuits and the last one is the design of a prototype for an automatic garden lighting system using the solar cell can be seen in Figure 5. And the prototype assembly flow diagram can be seen in Figure 6. Figure 7 is a prototype of a solar cell used in the prototype of an automatic garden light system using a solar cell, an accumulator, a current sensor, a voltage sensor, a relay, an ATMEGA328 microcontroller, LCD. Meanwhile, Figure 8 is a prototype of an automatic garden light system.

4.2.2. Validation test of prototype automatic garden lighting system products

After the assembly of the automatic garden light system prototype has been completed, testing is carried out so that there are no problems in using it. The aspects to be tested are shown in Table 14. The test results stated that all aspects worked very well, 89.14%. Next, measurements were carried out on physical variables including current, voltage, and power, which can be seen in Table 15.

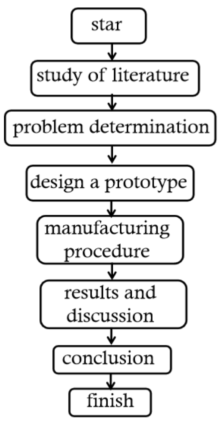

Figure 5. Flow diagram for making a prototype of an automatic garden lighting system

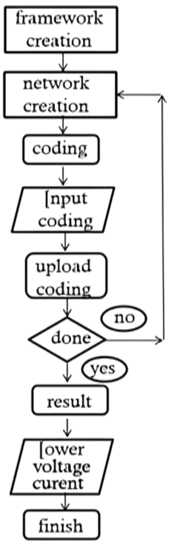

Figure 6. Flow diagram for prototype assembly of the automatic garden light system

Figure 7. Prototype of a solar cell

Figure 8. Prototype of an automatic garden light system

Table 14. Prototype assessment results

Feasibility aspect	Percentage
Material	91%
Time	88%
Objective	91%
Benefit	92%
Design	91%
Practical	90%
Quality	81
Average	89.14

Table 15. Data from current, voltage, and power measurements based on light intensity

No	Intensity light	Series circuit			Series circuit		
		I (A)	V(volt)	P(watt)	I (A)	V(volt)	P(watt)
1	318	0.06	32.00	1.92	0.22	12.00	2.64
2	399	0.05	28.35	1.42	0.10	12.25	1.23
3	471	0.05	28.35	1.42	0.56	18.25	10.22
4	658	0.11	24.00	2.64	0.56	18.25	10.22
5	957	0.12	17.24	2.07	0.12	17.20	2.06
6	1190	0.28	38.42	10.76	0.56	19.21	10.76
7	1198	0.55	38.98	21.40	0.55	19.00	10.45
8	1271	0.23	36.50	8.40	0.55	19.00	10.45
9	1291	0.55	19.33	10.63	0.54	19.30	10.42

From Table 16, it can be seen that current, voltage, and power are directly proportional to light intensity. The research results show that solar cells have an efficiency of 13% for series circuits and 14% for parallel circuits. From the test results, results were obtained which stated that all aspects worked very well at 89.14%. This finding is in line with the findings of other researchers regarding a prototype design for utilizing sunlight as an energy source through solar cells, such an electrical mechanism that the efficiency or quality of the solar panels is not compromised [37]-[43]. This environmentally friendly technology practical guidebook was carried out through a validation test by three media expert lecturers and one science teacher, using the Aiken validation index with (8).

$$V = \frac{\sum(\mathbf{r-Io})}{[\mathbf{n(c-1)}]} \quad (8)$$

The above quantities mean the number given by the assessor = r, the lowest validity assessment score = Io, the highest validity assessment score = c, and the number of assessors = n. After carrying out a validation test by 1 teacher and 3 lecturers, the results were obtained as shown in Table 16. From Table 16, it can be seen that the practicum guidebook is very suitable (90.75%) to be used as a practicum guide for environmentally friendly technology. The validation sheet assessment items look like Table 17.

To obtain students' thinking skills after using the environmentally friendly technology practicum manual, a pretest and post-test were carried out on class IX MTS Rahmatullah students. The purpose of this test is to determine the minimum, maximum, average score, and standard deviations for both pre-test and post-test scores. The test results can be seen in Tables 18 and 19.

Based on Table 19 values N_{gain} can be calculated as:

$$N_{gain} = \frac{(X_2-X_1)}{(X_3-X_1)} = \frac{(86.8636-36.3182)}{(100-36.3182)} = \frac{(50.5454)}{(63.6818)} = 0.7937$$

From the calculations, it can be seen that the value of 0.7937 is in the high category. The smallest t-count (4.41) > t-table (2.042). therefore, it can be concluded that all the items in each essay question can be declared valid for use in the next stage of research instruments. To determine learning completeness, the highest score, lowest score, average score, and standard deviation during the pretest and posttest can be seen in Tables 20 and 21. Meanwhile, the validity of the test is obtained with statistical data using SPSS 25, the results are obtained in Table 22. Reliability test results for pretest and post-test questions are shown in Table 23.

Table 16. Results of the assessment of the practicum guidebook

Feasibility aspect	Percentage	Category
Content	91%	Very worthy
Presentation	92%	Very worthy
Language	90%	Very worthy
Graphics	90%	Very worthy
Average	90.75%	Very worthy

Table 17. Validation sheet design for the practicum guidebook

Assessment indicators	Assessment items
Content eligibility	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,
Feasibility of presentation	18,19,20,21,22,23,24,25,26.27
Language assessment	28,29,30,31,32,33,34,35
Graphic aspects	36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52, 53,54,55,56,57,58,59,60,61

Table 18. Pre-test and post-test

Pre-test	Treatment	Post-test
36.31	X	86.86

X = Environmentally friendly technology practicum guidebook

Table 19. N-Gain results data

	N	Minimum	Maximum	Mean	Std. Devi
Pretest	22	29.00	43.00	36.3182	4.05188
Post test	22	80.00	93.00	86.8636	5.02655
N-gain	22	.68	.89	.7926	.08093
Valid N (listwise)	22				

Table 20. Pretest and posttest criteria

Criteria	Pretest	Post test	Criteria	Pretest	Post test
Lowest value	29	80	Average student score	36.312	86.863
The highest score	43	93	Not completed	30	0
Minimum completeness criteria	75	75	Completeness	0%	100%

Table 21. Data on pretest and post-test results

Test pair	Test	Mean	N	Std. Dev.	Std. error mean
Pair 1	Pretest	36.3182	22	4.05188	.86386
	Posttest	86.8636	22	5.02655	1.07166

Table 22. Results of the validation of the question item

Question items		1	2	3	4	5	6	7	8	9	10	
Total	Pearson correlation	.872**	.806**	.881**	.703**	.766**	.626**	.713**	.697**	.601**	.840**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	

Table 23. Reliability results of pretest and post-test questionnaires

Reliability statistics	
Cronbach's Alpha	N of items
.914	10

4.2.3. Teacher and student response test

Quasi-experiments on class IX samples at MTS were used for product implementation. The test used to determine teacher and student responses to the Environmentally Friendly Technology Practicum Manual is used. Teacher and student response sheets are processed with the percentage of respondents who agree or disagree. This test was applied to class IX students at MTS Rahmatullah. Teacher and student responses have a high percentage score as seen in the results of the teacher and student response questionnaire to the practice guidebook, which can be seen in Table 24.

From the data above, it turns out that the use of the Environmentally Friendly Technology Practical Guidebook, based on the automatic solar cell garden light system, can improve students' thinking abilities in the "high category" and "almost all" students and teachers respond well to it. These findings are in line with research on the analysis, design, development, implementation, and evaluation (ADDIE) model using program guides and solar panel STEM KITs, which can increase students' interest in STEM learning activities. This may be due to several things, such as similar content and activities, similar involvement, and similar guidance [44]. Through an inquiry approach, learning in junior high school can equip students with the ability to understand solar energy, how sunlight is converted into electrical energy. Students are able to assemble solar cells to produce electrical energy, are able to store electricity from solar energy in batteries and use them in everyday life [45]. Students and teachers were indicated to have gained a lot of knowledge to improve lesson delivery and classroom management after participating in the practicum activities [46].

Students' responses to the practical work on making pineapple candy on the sub-material of the role of plants in the economic field obtained an average percentage of 83.33% and were included in the very high category. Responses were supported by students' attitude scores with an average score of 92.06, including the very high category, while students' skill scores had an average score of 88.27 and included the very high category [47]. The research used a pre-test short case study experimental design. The success of using the method was assessed by the number of students who scored above the minimum passing criteria (KKM) in science, namely 70. The results obtained by students who scored 86-100 were 45.4%, 36.4% scored 70-85, 55%. -69 is 18.2%, and 0-54 is 0%. This means that students' scores above the KKM are 81.8% [48]. The study was designed to assess the practices and challenges faced by Teaching English as a Second Language (TESL) students in teacher training institutions during practicums in selected primary schools in Malaysia. Research findings show that: student-teachers have positive perceptions of the role of practicum programs in improving pedagogical skills as well as subject matter knowledge; student-teachers can understand themselves better throughout the month of practicum. The ability to self-monitor and self-assess is a valuable skill that these student-teachers must acquire to be effective in their personal and autonomous ongoing self-assessment. After 8-12 weeks of practicum at school which aimed to determine the impact of the practicum approach, the practicum assessment model, on the level of readiness of student teachers to teach, it was found that students and teachers were indicated to have gained a lot of knowledge to improve lesson delivery and classroom management [49], [50].

Table 24. Questionnaire results for teacher and student responses to the guidebook

Item	Teacher response	Student response
Total score	183	1176
Maximum score	200	1320
percentage	91.50%	89.9%
Response category	Almost all of it	Almost all of it

5. CONCLUSION

Based on the needs analysis, it is known that the core competencies and basic competencies in the curriculum are in accordance with the material developed so that students are able to understand alternative electrical energy. According to students, the existing teaching material aspects, content aspects, and difficulty aspects are inadequate. Students show high interest when given a science practical guidebook. The intensity of sunlight affects current, voltage, and power. The prototype of the automatic garden lighting system and the practical guidebook are very suitable for use; this can be seen from the suitability of the tools, materials, response time, purpose, benefits, design, practicality, and suitability of quality contained in the automatic garden lighting system. Meanwhile, the science practicum guidebook is very suitable for use with indicators of suitability of content, presentation, language and graphic suitability which are very suitable for use. Based on the results of teachers' and students' responses to the science practicum manual for environmentally friendly technology using solar cells, almost all students and teachers gave responses that were categorized as very good. For this reason, the author suggests that teachers can use renewable energy tools and teaching materials, so that students realize from an early age the importance of using renewable energy to anticipate a reduction in the availability of fossil-based energy, which is less environmentally friendly.

ACKNOWLEDGMENTS

Thanks are expressed to Dr. Alexon., M.Pd. as Dean of the Faculty of Teacher Training and Education, Bengkulu University, and Dr. Euis Nursaadah as Coordinator of the Natural Sciences

Postgraduate. Program, Faculty of Teacher Training and Education, Bengkulu University, who has given permission and facilitated this research.

FUNDING INFORMATION

This research was funded by the Postgraduate Program of the Faculty of Teacher Training and Education, Bengkulu UNIVERSITY for the 2023/2024 academic year. Funded by DIPA/RBA FKIP UNIB in 2024. Contract Number: 4924.j/UN30.7/LT/2024 Date: 8-31-2024.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration. All authors contributed to the conception, design, and finalization of the work.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Each author in this work agrees to declare that we have no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

REFERENCES

[1] I. Overland, "Energy: the missing link in globalization," *Energy Research and Social Science*, vol. 14, pp. 122–130, 2016, doi: 10.1016/j.erss.2016.01.009.

[2] E. P. Laksana *et al.*, "Potential usage of solar energy as a renewable energy source in Petukangan Utara, south jakarta," *Jurnal Rekayasa Elektrika*, vol. 17, no. 4, Dec. 2021, doi: 10.17529/jre.v17i4.22538.

[3] T. M. Kibtiah, G. D. P. Dewi, A. Bainus, M. F. Abdurrahman, D. RHasan, and K. M. Suitela, "Solar energy in indonesia: the implementation of sustainable development goals for net zero emissions," *IOP Conference Series: Earth and Environmental Science*, vol. 1324, no. 1, p. 012093, Apr. 2024, doi: 10.1088/1755-1315/1324/1/012093.

[4] B. Harianto and M. Karjadi, "Planning of photovoltaic (PV) type solar power plant as an alternative energy of the future in indonesia," *ENDLESS: International Journal of Future Studies*, vol. 5, no. 2, pp. 182–195, Aug. 2022, doi: 10.54783/endlessjournal.v5i2.87.

[5] T. Maidasari, L. Y. Prakoso, and S. Murtiana, "Renewable energy as a green economy stimulus in Indonesia," *Jurnal Energi Baru dan Terbarukan*, vol. 4, no. 3, pp. 183–191, Dec. 2023, doi: 10.14710/jebt.2023.18496.

[6] E. S. Nasution, A. Hasibuan, W. V. Siregar, and R. Ismail, "Solar power generation system design: case study of North Sumatra Muhammadiyah University building," in *2020 4rd International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, IEEE, Sep. 2020, pp. 191–194. doi: 10.1109/ELTICOM50775.2020.9230526.

[7] K. S. Faraj, "Design and analysis of a photovoltaic (PV) system for residential applications," *Lambert Academy Publishing* (LAP), pp. 1–54, 2023, [Online]. Available: https://www.researchgate.net/publication/370211403

[8] K. Ronay and C. D. Dumitru, "Technical and economical analysis of a solar power system supplying a residential consumer," *Procedia Technology*, vol. 22, pp. 829–835, 2016, doi: 10.1016/j.protcy.2016.01.056.

[9] E. Osekowska and B. I. of Technology, "Design and implementation of a maritime traffic modeling and anomaly detection method," *Blekinge Institute of Technology Licentiate Dissertation Series*, no. 2014:09, p. 129, 2014.

[10] A. Razmjoo, A. Ghazanfari, P. A. Østergaard, and S. Abedi, "Design and analysis of grid-connected solar photovoltaic systems for sustainable development of remote areas," *Energies*, vol. 16, no. 7, 2023, doi: 10.3390/en16073181.

[11] L. Halim, S. E. Gun, and F. Wahab, "Solar panel efficiency improvement through dual-axis solar tracking with fuzzy logic and water treatment techniques," *Jurnal Nasional Teknik Elektro*, pp. 20–29, 2023, doi: 10.25077/jnte.v12n3.1120.2023.

[12] A. S. Falah, D. Fauziah, and T. J. Sujana, "Battery inspection of 380 kwp off-grid solar power plant (PLTs) on mules island, east nusa tenggara," *REKA ELKOMIKA: Jurnal Pengabdian kepada Masyarakat*, vol. 5, no. 1, pp. 89–98, Jan. 2024, doi: 10.26760/rekaelkomika.v5i1.89-98.

[13] A. O. M. Maka and J. M. Alabid, "Solar energy technology and its roles in sustainable development," *Clean Energy*, vol. 6, no. 3, pp. 476–483, Jun. 2022, doi: 10.1093/ce/zkac023.

[14] M. Soheilian, G. Fischl, and M. Aries, “Smart lighting application for energy saving and user well-being in the residential environment,” *Sustainability*, vol. 13, no. 11, p. 6198, May 2021, doi: 10.3390/su13116198.

[15] M. Temiz and I. Dincer, “Design and assessment of a solar energy based integrated system with hydrogen production and storage for sustainable buildings,” *International Journal of Hydrogen Energy*, vol. 48, no. 42, pp. 15817–15830, May 2023, doi: 10.1016/j.ijhydene.2023.01.082.

[16] D. Rahmawati, B. S. Aprillia, W. Priharti, D. K. Silalahi, and K. Kumillayla, “Design of automatic switch system of solar panel and power plant for residential load using artificial neural network,” *IOP Conference Series: Materials Science and Engineering*, vol. 771, no. 1, p. 012008, Mar. 2020, doi: 10.1088/1757-899X/771/1/012008.

[17] N. Desysetyowati, I. Mudrikah, R. T. Lintangesukmanjaya, M. W. Arrahmat, Dwikoranto, and N. Suprapto, “Development of sound resonance measuring tools android based sound level meter (slm) as a physics demonstration tool,” *Conference: Electronic Physics Informatics International Conference (*EPIIC*)*, 2024, p. 060052. doi: 10.1063/5.0210754.

[18] M. Salama, M. Nour, A. Haloub, and Y. Al Jundi, “Renewable energy for sustainable development,” *Principles of Sustainable Project Management*, pp. 323–340, 2025, doi: 10.2307/jj.28209978.17.

[19] P. A. Østergaard, N. Duic, Y. Noorollahi, and S. Kalogirou, “Advances in renewable energy for sustainable development,” *Renewable Energy*, vol. 219, 2023, doi: 10.1016/j.renene.2023.119377.

[20] I. Dincer, “Renewable energy and sustainable development: a crucial review,” *Renewable & Sustainable Energy Reviews*, vol. 4, no. 2, pp. 157–175, 2000, doi: 10.1016/S1364-0321(99)00011-8.

[21] N. A. Pambudi *et al.*, “Renewable energy in indonesia: current status, potential, and future development,” *Sustainability*, vol. 15, no. 3, p. 2342, Jan. 2023, doi: 10.3390/su15032342.

[22] Masthura and Abdullah, “Effect of temperature and sunlight intensity on surface of solar panels on electric power generated,” *Journal of Physics: Conference Series*, vol. 2733, no. 1, p. 012029, Mar. 2024, doi: 10.1088/1742-6596/2733/1/012029.

[23] Z. Li, J. Yang, and P. A. N. Dezfuli, “Study on the influence of light intensity on the performance of solar cell,” *International Journal of Photoenergy*, vol. 2021, pp. 1–10, Feb. 2021, doi: 10.1155/2021/6648739.

[24] N. U. Putri, E. Pranita, J. P. Sembiring, A. Jayadi, A. Aryanto, and F. K. Muzamil Suat, “The effect of solar radiation on solar panels in aeroponic plant systems,” in *2023 International Conference on Networking, Electrical Engineering, Computer Science, and Technology (IConNECT)*, IEEE, Aug. 2023, pp. 121–126. doi: 10.1109/IConNECT56593.2023.10327307.

[25] P. H. Ganvir, W. V. Patil, and S. R. Sonaskar, “Smart solar street light using iot: an energy-efficient approach to urban lighting,” in *2024 4th International Conference on Ubiquitous Computing and Intelligent Information Systems (ICUIS)*, IEEE, Dec. 2024, pp. 1745–1749. doi: 10.1109/ICUIS64676.2024.10866668.

[26] M. Hamid, M. F. Simamora, M. D. E. Vania, and P. Cholillah, “Design of automatic cleaning system on solar panel using iot-based wiper,” *Journal of Physics: Conference Series*, vol. 2733, no. 1, p. 012024, Mar. 2024, doi: 10.1088/1742-6596/2733/1/012024.

[27] H. M. Yasin, S. R. M. Zeebaree, and I. M. I. Zebari, “Arduino based automatic irrigation system: monitoring and sms controlling,” in *2019 4th Scientific International Conference Najaf (SICN)*, IEEE, Apr. 2019, pp. 109–114. doi: 10.1109/SICN47020.2019.9019370.

[28] M. B. I. Astutiningtyas, M. M. Nugraheni, and S. Suyoto, “Automatic plants watering system for small garden,” *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 15, no. 02, p. 200, Jan. 2021, doi: 10.3991/ijim.v15i02.12803.

[29] A. S. Budi, “Design of automatic garden watering based on solar cell,” *Brilliance: Research of Artificial Intelligence*, vol. 2, no. 1, pp. 13–16, May 2022, doi: 10.47709/brilliance.v2i1.1507.

[30] S. Kiwan, A. Abo Mosali, and A. Al-Ghasem, “Smart solar-powered LED outdoor lighting system based on the energy storage level in batteries,” *Buildings*, vol. 8, no. 9, p. 119, Aug. 2018, doi: 10.3390/buildings8090119.

[31] H. M.Saleh and A. I.Hassan, “The challenges of sustainable energy transition: a focus on renewable energy,” *Applied Chemical Engineering*, vol. 7, no. 2, p. 2084, Apr. 2024, doi: 10.59429/ace.v7i2.2084.

[32] Ishtiaq Ahmed and Sundas Ishtiaq, “Reliability and validity: importance in medical research,” *Journal of the Pakistan Medical Association*, vol. 71, no. 10, pp. 2401–2406, Jul. 2021, doi: 10.47391/JPMA.06-861.

[33] E. Chetwynd, “Critical analysis of reliability and validity in literature reviews,” *Journal of Human Lactation*, vol. 38, no. 3, pp. 392–396, Aug. 2022, doi: 10.1177/08903344221100201.

[34] M. Silvia and I. Irwansyah, “Validity and reliability test of content creator strategy management,” *Jurnal Kajian Jurnalisme*, vol. 6, no. 2, p. 158, Jan. 2023, doi: 10.24198/jkj.v6i2.43348.

[35] L. R. Gay, G. E. Mills and P. Airasian, *EducationaL competencies for analysis and applications causal-comparative*, 10th ed. Boston, Pearson, 2012.

[36] W. Park and S.-G. Kim, “Integrating quantitative and qualitative methodologies to build a national R&D plan using data envelopment analysis based on R&D stakeholders’ perspectives,” *PLOS ONE*, vol. 17, no. 3, p. e0265058, Mar. 2022, doi: 10.1371/journal.pone.0265058.

[37] G. Kumaravel and V. Ilankumaran, “IoT based smart battery power and wastage level tracking system for solar powered waste bin by gsm technology,” *IOP Conference Series: Earth and Environmental Science*, vol. 1055, no. 1, 2022, doi: 10.1088/1755-1315/1055/1/012014.

[38] A. Tilmatine, N. Kadous, K. Yanallah, Y. Bellebna, Z. Bendaoudi, and A. Zouaghi, “Experimental investigation of a new solar panels cleaning system using ionic wind produced by corona discharge,” *Journal of Electrostatics*, vol. 124, p. 103827, Jul. 2023, doi: 10.1016/j.elstat.2023.103827.

[39] S. Das, P. Sadhu, N. Pal, and S. Mukherjee, “Single axis automatic solar tracking system using microcontroller,” *TELKOMNIKA Indonesian Journal of Electrical Engineering*, vol. 12, no. 12, Dec. 2014, doi: 10.11591/telkomnika.v12i12.6742.

[40] N. T. K. and Prashanth, “Design and development of solar panel tracking mechanism,” 2018, p. 020014. doi: 10.1063/1.5078973.

[41] Z. J. Tang, P. Z. Yang, and T. Zhang, “The research and design of automatic tracking system of the light based on the logo controller,” *Advanced Materials Research*, vol. 724–725, pp. 195–199, Aug. 2013, doi: 10.4028/www.scientific.net/AMR.724-725.195.

[42] H. Farahmand, L. Warland, and D. Huertas-Hernando, “The impact of active power losses on the wind energy exploitation of the north sea,” *Energy Procedia*, vol. 53, pp. 70–85, 2014, doi: 10.1016/j.egypro.2014.07.216.

[43] M. Jesús Hermoso-Orzáez and A. Gago-Calderón, Energy efficiency and sustainable lighting: a bet for the future. Erscheinungsort Nicht Ermittelbar: Intech Open, 2020.

[44] A. Suryadi, N. Lidya, H. Habibah, and I. P. Suwarna, “Study on the development and implementation of an interdisciplinary solar panel project to enhance students’ interest in stem,” *Research and Development in Education (RaDEn)*, vol. 4, no. 1, pp. 415–427, May 2024, doi: 10.22219/raden.v4i1.32881.

[45] Y. M. Cholily, A. In’am, S. Inganah, and M. M. Effendi, “The learning of the solar cell electricity among the students in junior high school,” *Energy Economics Letters*, vol. 6, no. 1, pp. 17–22, 2019, doi: 10.18488/journal.82.2019.61.17.22.
[46] E. F. S. Rini and F. T. Aldila, “Practicum activity: analysis of science process skills and students’ critical thinking skills,” *Integrated Science Education Journal*, vol. 4, no. 2, pp. 54–61, May 2023, doi: 10.37251/isej.v4i2.322.
[47] Á. R. Gallardo, “The function theory and its application on manuals of economics,” *HERMES - Journal of Language and Communication in Business*, no. 50, pp. 83–95, Nov. 2017, doi: 10.7146/hjlcb.v26i50.97807.
[48] D. M. Switzer and M. L. Connell, “Practical applications of student response analysis,” *Educational Measurement: Issues and Practice*, vol. 9, no. 2, pp. 15–17, Jun. 1990, doi: 10.1111/j.1745-3992.1990.tb00363.x.
[49] R. Sathappan and P. Gurusamy, “The practice and challenges of practicum implementation program at a malaysian teacher education institute,” *Journal of Social Science Research*, vol. 14, pp. 3234–3243, Jul. 2019, doi: 10.24297/jssr.v14i0.8324.
[50] P. Brett *et al.*, “Learning the words: supervising teachers and the language of impact in an initial teacher education programme,” *Australian Journal of Teacher Education*, vol. 43, no. 8, pp. 105–122, Aug. 2018, doi: 10.14221/ajte.2018v43n8.7.

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