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An Instructional Trainer for the Photovoltaic Panel on A-Grade Mono Crystalline Solar Cells: An Innovation

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Abstract:
The present study determined the effectiveness of an instructional trainer for the photovoltaic panel on A-grade mono crystalline solar cells. A developed 150 watts PV module, charge controller, pure sine-wave inverter deep cycle battery, analog meters, and digital monitoring instruments were used for demonstration, illustration, and testing respondents' awareness on climate change, solar energy, analytical skills in electrical circuit, practical knowledge in test and measurement. The participants of the study were TLE students at the Division of Engineering Technology of the Mindanao State University-Marawi. This study adopted quantitative research methods, namely single-group pre-test-post-test design and survey questionnaires to collect the necessary data. Descriptive statistics (means, percentages and standard deviations) and inferential statistics (one-tailed Paired Samples t-Test) were used to analyze the gathered data. Findings show that majority of the students got a good rating in the pre-test. After the intervention using the solar instructional module, their post-test performance significantly improved, which was generally rated as very good. When the instructional trainer was evaluated by both students and experts, they general rating was good in terms of aesthetics, functionality, reliability, and safety. It is recommended that schools use this innovative solar instructional trainer in teaching students concepts about climate change, solar energy, electric circuit, and test and measurement. It is also suggested that experts and researchers may adopt this study as basis for their future research and other endeavors for the benefit of the public.

Key words: Instructional Trainer, Photovoltaic Solar Module, Climate Change, Solar Energy, Electrical Circuit

I. INTRODUCTION

The most serious and obvious problem the world faces today is climate change. As a consequence, enormous imminent harms can potentially damage the world and affect human lives. Human activities are identified to emit additional greenhouse gases, particularly carbon dioxide (CO_2), through continues burning of fossil fuel in coal-fired power plants, transportation, among others. The vanishing of forest further aggravates the problem because fewer trees absorb CO_2. In effect, the great amount of harmful gases accumulated, thereby greatly affecting the natural chemistry of the planet. The Philippines is in the Ring of Fire vulnerable to different natural calamities like typhoon, earthquake, as well as extreme weather conditions, temperature increase, sea level rise, shifting rainfall patterns, etc. On the other hand, the Philippines is a fertile ground of free electricity from the Sun, which is equivalent to 5kWh/m2 per day. However, due to absence of machineries, the country is now one of the producers of dirty and expensive electricity in Southeast Asia and the world. The whole country is experiencing power shortages due to increase in population, businesses, and many energy-consuming infrastructures. The power demand and the number of power-generating plants obviously mismatched. In view of this, a long-term and environment-friendly solution, pertaining to solar and other renewable sources of energy, should be adopted to generate free and clean energy for all.[1] Simplified Method of Encapsulating Fragile PV Cells for Cottage Industry Production of Photovoltaic Modules" pointed out that half of the people living in rural areas of developing countries have no access to utility grids. Photovoltaic (PV) electricity is often the ideal solution to the problem of furnishing consumers with electricity. However, the PV system is generally far too expensive for the average rural individual to afford, and an entire infrastructure needs to be created for the installation and maintenance of these systems. One possible solution to this problem is to teach people how to build and install their own PV systems. This led to the development of photovoltaic as a cottage industry where the people, including villagers in the developing world, could make and install their own PV systems. Although there is already an existing study on the advantages and development of low-cost photovoltaic modules in other countries, many are complaining due to high cost of electricity and are now interested to switch to solar power energy. However, initial cost in solar installation is still the biggest hindrance to almost every Filipino. There is a prevailing lack of information drive, and support. In addition, ignorance on the advantages and importance of solar energy system by concerned government agencies including educational institutions also aggravates the situation.

With this pressing scenario, the need for an effective means to disseminate specifically to students the information on the importance of solar energy as one of the reliable sources of free energy coming from the environment, the process of making a solar panel, and the principles in charge controller, inverter, battery and proper solar power system installation. Solar power needs no further exploration; no one can monopolize, there are no moving parts, noiseless, and easy to implement. More

importantly, it does not produce carbon footprint and pollution, has less maintenance, and is affordable. Further, solar power is the best way to cut-down monthly electric bills, increase house market value, and address environmental issues. With its practical application, the researcher was motivated to design and evaluate the effectiveness of a low-cost 150 watts PV system module as an instructional trainer for the awareness of students on renewable and sustainable energy. With this module, people are hoped to appreciate the value of switching to renewable energy to curb carbon footprints which is identified by many scientists to cause climate change.

The design of the photovoltaic module and as an instructional trainer introduces an innovation on the procedure sofmanu fracturing a locally-made photovoltaic system. Moreover, it also includes necessary instruments and other facilitative features that help in the learning process undergone by students with regard to renewable energy, thereby increasing appreciation towards it.

II. RELATED WORK AND INVENTION

Several learning theories and concrete teaching models/materials have evolved and been continuously modified to meet the needs of the learners from generation to generation. [2] Teachers at all levels utilize a variety of instructional materials such as textbooks, presentations and handouts to enhance the quality of their lessons. The quality of those materials directly impacts the quality of teaching. Knowing how to find the best instructional materials is a valuable skill for a teacher to have. He added that professors and teachers should ensure they assign or use instructional materials that are on pace with knowledge in the field. [3] Development of instructional electronic material or e-material for electrical and electronic studies was developed by many companies and institutions. Moreover, using technology into teaching and learning was preferred by technical teachers and students and e-material as a tool which will be enhanced to understand the subject of electrical and electronics as well.

Assuredly, the teachers have masterly integrated in the e-material with their process of teaching and the students have to properly integrate into their learning. [4] Educational technology in teaching is of great importance because of the use of information and communication technologies. With the help of various applications for distance education, the internet, teachers, and teachers themselves, they see advantages of educational technology. [5] Disclosed present invention US 9099587B2 which relates to an educational solar cell module. Accordingly, the electrodes of the solar cells can be easily connected and removed from each other in series or in parallel, and the variations in voltage and current according to the number of connected solar cells can be observed easily to increase interest in solar energy. His claim was a solar cell module for use as a teaching aid comprising a frame, a solar cell panel bonded to an upper side of the frame, and a frame coupling member provided to the frame and coupling adjacent frames to each other such that the frames are continuously coupled and arranged.[6] Solar energy utilization having various modules with different forms of energy collection coupled to maximize efficiency. The model comprises a support board on which a photovoltaic cell module is mounted, coupled to electrical storage batteries, together with a solar collector coupled to a thermal energy circuit and a heliostat module with solar mirrors and a solar- powered boiler. All the different forms of energy collection and utilization are interconnected, so as to increase the overall efficiency. The solar-powered boiler drives a steam motor, in turn driving on electricity generator connected to the electrical storage batteries, with the heated water circulating around the thermal energy circuit providing the supply reservoir for the boiler. The model may also incorporate further modules powered by different forms of alternative energy, e.g. a windmill and a hydraulic module.

A number of studies purport that laboratory exercises and simulations play an important role in learning. For one, [7] Learning by doing helps students perform better in science. Students who physically experience scientific concepts understand them more deeply and score better on science tests. [8] Engineering and engineering technology courses are taught is through traditional lecture and laboratory experiments, which are still the most frequent teaching methods used nowadays around the world. On the other hand, active learning methodologies grounded in scientific research in education have been attracting considerable attention over the past years with numerous research studies indicating the efficacy of such learning styles. In terms of learning content, [9] Electricity is an important and challenging science topic at all school levels. Learners often have many difficulties in learning electricity.

Previous attempts to overcome these difficulties have been rather one-sided, leaning only on one method at the time, and thus ineffective. As a solution, a learning environment which combines the strengths of traditional laboratory exercise and simulation working with tasks that structure student work and explicitly address common difficulties in learning electricity was developed. Moreover, the simulation-laboratory-combination environment was particularly effective. It improved more effectively students overall knowledge of DC circuits and facilitated the development of scientifically acceptable models of current flow and current division. The use of simulation-based labs has been gaining currency in the domains of engineering and technology programs. [10] Laboratories are critical to enable learners, such as engineering students, to develop knowledge and skill. However, labs are costly, time-consuming, and difficult to schedule since sessions may require two or three hours each—often in afternoons or on weekends when students have fewer conflicts with other courses. Moreover, a lab assistant must be in constant attendance to coach and to answer questions. Further, [11] The advantages of using simulation software, to wit: allowing the user to modify system parameters and observe the outcomes without any harmful side effects, eliminating component or equipment faults that affect outcomes, supporting user paced progress in discovery and understanding of miss users, and allowing the presentation of “dry theory” in another way. System simulation is necessary to investigate the feasibility of Solar PV system at a given location.

The previous year, 2017, was so far the hottest year that was not affected by the El Nino weather event, [12] El Nino has been used to explain rising temperatures and occasionally to suggest that the temperature is not warming at all. The new finding shows that the climate is in fact warming rapidly, even without the effect of the El Nino which pushes up temperatures across

the world. Already, 2016 and 2015 were the hottest years yet. All coastal Centers show significant sea level rise trends, mirroring global and national trends. Sea level rise of between 6 and 29 inches by the 2050s is projected for NASA's five coastal Centers along the coast. New maps of Greenland's seafloor and bedrocks show that two out of the four times as many coastal glaciers are at risk of accelerated melting as previously thought. The planet's average surface temperature has risen about 2.0 degrees Fahrenheit (1.1 degrees Celsius) since the late 19th century, a change driven largely by increased carbon dioxide and other human-made emissions into the atmosphere. Most of the warming occurred in the past 35 years, with 16 of the 17 warmest years on record occurring since 2001. [13]Potential future effects of global climate change include more frequent wildfires, longer periods of drought in some regions and an increase in the number and duration and intensity of tropical storms. The range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time. In an article [14] Photovoltaic modules are designed to meet the reliability and safety requirements of national and international test standards. Qualification testing is a short-duration (typically, 60-90 days) accelerated testing protocol, and it may be considered as a minimum requirement to undertake reliability testing.

The goal of qualification testing is to identify the initial short-term reliability issues in the field, while the qualification testing /certification is primarily driven by marketplace requirements. Safety testing, however, is a regulatory requirement where the modules are assessed for the prevention of electrical shock, fire hazards, and personal injury due to electrical, mechanical, and environmental stresses in the field. [15] Efficiency of solar cells is determined according to standard test conditions (STC), and he added that panel manufacturer guarantees a minimum power reliability of 25 years. PV panels were exposed to reliability tests and treated with thermal cycling tests (TC) and damp heat tests. In addition photovoltaic modules are designed to meet the reliability and safety requirements of national and international test standards. Qualification testing is a short-duration (typically, 60-90 days) accelerated testing protocol, and it may be considered as a minimum requirement to undertake reliability testing. He added that qualification testing is a set of well-defined accelerated stress test sir radiation, environmental, mechanical and electrical with strict pass-fail criteria based on functionality /performance, safety/insulation, and visual requirements. The related literature, studies, and inventions cited were used as the motivation and guides in the conduct of this study. The design and development of the PV Module as an instructional trainer will not only serve as medium for awareness but also as inspiration to people that a renewable energy source like the solar can be locally assembled with less cost.

III. RESEARCH DESIGN AND METHODOLOGY

This study employed single group pre-test-post-test design. This involves one (1) section of second year TLE students taking basic electricity-electronics courses in the Division of Engineering Technology (DET). In this kind of design, pre-test is given to all participants before application of the experimental remedy and the post-test is given at the end of the experiment. Results of the test are tabulated and analyzed using appropriate statistical tools by comparing the pre-test and post-test results. Three sets of instruments were used to collect the data needed in this study. First was a set of pre-test and post-test questionnaires that tested the knowledge of the participants on climate change, solar energy, electrical circuit, and test measurement. The performance of the participants were identified through the scores they received in the tests. Then accompanying each ^{pre}-test and post-test questionnaire were survey questionnaires that assessed the participants' conception and awareness of specific details in each of the topics tested. They responded to the said instruments through choosing yes or no for every indicator. The last set of instrument required the participants to assess the level of acceptability of the instructional material. Four criteria were used to assess the said material, to wit: aesthetics, functionality, reliability, and safety.

Test-retest reliability within 2 weeks interval was used to establish the reliability co-efficient of the instruments. This method is a measure of stability of instrument overtime. It was obtained by administering the questionnaires to a group of individuals and then re-administering the same questionnaire to the same individual at a later date and correlating the two set of scores. Before the commencement of the design process proper, the proponent considered the information on PV module demand and the advantages and disadvantages of PV solar power system compared to other renewable energy sources locally here and abroad. Technique sin assembling solar module with or without using expensive laminating machines and the availability of materials tools and equipment were also given ample consideration. Moreover, using solar power system at home can mitigate greenhouse effect, can save energy, money, and can preserve the environment. The proposed device consists of mono crystalline PV cells which has a characteristic of converting sunlight energy into electrical energy around 0.5 volts dc output for single cell.

These PV cells are connected in series to increase the amount of voltage and current to charge-up 12 volts lead acid batteries. Reliability and safety of the module during long term operation must also be considered. Factors to be considered are the environmental stress as well as physical and electrical stresses through lamination and framing process. The stored current in day time can be used during night time or during cloudy days. Utilizing charge controller, battery, and inverter is suited if power utility supplier is not available, it is a stand -alone set-up. Initial estimated power output is 150watts, 18 volts as maximum voltage, and 8 amperes is the maximum current output of the proposed photovoltaic module based on the size and electrical characteristic of single A-grade mono crystalline cell. In addition, basic ohm's and power law equation is used in the load capacity computation to determine the effective electrical energy output that can operate home appliances such as lightings, television, computers, cellular phones, laptops, and phantom load.

Furthermore, since the device is an instructional trainer, the design also considers the objective of the course, which is fostering awareness to students on the principle of photovoltaic (PV) cell as well as the methods in assembling a PV module, proper connection of charge controller, inverter, battery, DC and AC load, and different monitoring instruments to easily observe and monitor the condition of the entire PV solar power system.

V. RESULTS

Figure 1.PV Solar Instructional Material

Figure 2. Student Monitor Voltage output using Floodlight

DATA PRESENTATION, ANALYSIS AND FINDINGS

Table 1 Frequency and Percentage Distribution of Respondents in terms of their Overall Performance in the Pre-test

Description	Range	Frequency	Percentage Distribution	Mean / SD
Very Good	31-40	5	12.50%	26.60 / 4.53
Good	21-30	21	52.50%	
Poor	11-20	4	10.00%	
Very Poor	0-10	0	0.00%	

Indicators	Mean	SD	Description
Climate Change	7.00	1.70	Good
Solar Energy	7.00	1.68	Good
Electric Circuit	7.57	1.59	Good
Test and Measurement	5.03	2.79	Average

DISCUSS: The data show that majority (52%) of the respondents had an overall good performance in the pre-test. The overall rating is also good (mean=26.60). The standard deviation of 4.53 indicates that the respondents' over-all pretest varies a lot from each other.

Table.2. Frequency and Percentage Distribution of Respondents in terms of their Overall Performance in the Pos-test

Description	Range	Frequency	Percentage Distribution	Mean / SD
Very Good	31-40	29	72.50%	35.5 / 2.61
Good	21-30	1	2.50%	
Poor	11-20	0	0.00%	
Very Poor	0-10	0	0.00%	

Indicators	mean	SD	Description
climate change	9.07	1.01	Very Good
solar energy	9.37	0.76	Very Good
electric circuit	8.83	1.39	Good
test and measurement	8.23	1.99	Good

The data show that majority (73%) of the respondents got an overall rating of very good in the whole post-test, which is further supported by their overall mean of 35.5 described as very good. The standard deviation of 2.61 may indicate a wide dispersion of their scores, but this also means that many got high scores close to each other.

Table 3 Results of the Paired Samples t-Test Comparing Students' Pre-test and Post-test Scores

	Pre-test		Post-test		T-value	P-value
	Mean	Desc.	Mean	Desc.		
Climate change	7.00	Good	9.07	Very Good	5.712	3.65×10^{-07}
Solar energy	7.00	Good	9.37	Very Good	7.017	7.80×10^{-09}
Electric circuit.	7.57	Good	8.83	Good	3.282	0.0008
Test and measurement	5.03	Average	8.23	Good	5.116	2.20×10^{-06}
OVER-ALL	26.6	Good	35.50	Very	9.312	1.87×10^{-12}

The table 3 shows the results of the paired samples t-Test conducted to compare the pre-test and post-test scores of the students in all topics, namely climate change, solar energy, electric circuit, and test and measurement. Their overall scores were also compared.The null hypothesis stating there is no significant difference in the respondents' competencies in climate change, solar energy, electric circuit, and test and measurements when grouped according to types of test is rejected. This is based on the p-values which are less than the level of significance (α=0.05). In particular, the results reveal that the post-test performance of the respondents is significantly better than their pre-test performance, which is due to the application of the innovative instructional trainer.

Table 4 Frequency and Percentage Distribution of Respondents in terms of their Evaluation of the Solar Instructional Trainer

Description	Range	Frequency	Percentage Distribution	Mean / SD
Very good	4.80-5.00	17	48.57%	4.79 / 0.27
Good	3.90-4.79	18	51.43%	
Average	2.80-3.89	0	0.00%	
Poor	1.90- 2.79	0	0.00%	
Very poor	1.00-1.89	0	0.00%	

Criteria	N A	SA	A	MA	HA	Mean	Standard Deviation
Aesthetic	0	1	0	10	24	4.63	0.65
Functionality	0	0	0	6	29	4.83	0.38
Reliability	0	0	0	6	29	4.83	0.38
Safety	0	0	0	4	31	4.89	0.32

Legend: *NA (Not acceptable), SA (Slightly Acceptable), A (Acceptable), MA (Moderately Acceptable), and HA (Highly Acceptable)*

The data show that majority (51.43%) of the evaluators composed of 30 students and 5 experts evaluated the solar instructional trainer as a good material based on its aesthetic, functional, reliable, and safe quality. The overall rating of 4.79 is also within the range for "good." The standard deviation of 0.27 indicates that the evaluators' ratings are closely similar to each other.

VI. CONCLUSION

This study employed innovation by designing an instructional trainer for the photovoltaic panel. To reiterate, the goal was to determine its effectiveness in improving students' learning competencies and its acceptability as a material. The results revealed positive outcomes as regards the effectiveness of the trainer. This is evidenced by the significant improvement in the students' knowledge on climate change, solar energy, electric circuit, and test and measurement after they were taught using the said innovated trainer. To add, they exhibited awareness on climate change and its consequences, showed appreciation and interests in solar energy, and got an enhanced analytical skills and creativity in electrical circuit as well as in test and measurement. This purports the conclusion that the trainer is an effective instructional material that can be used in teaching concept and skills. In regard to its quality, the findings suggest that the solar instructional trainer is presentable as it is and serves the functions it was made to perform. It was also found to be reliable and safe, which add to its viability and palatability if introduced to mainstream institutions and teachers of electronics and its related fields. Therefore, this innovative material does not only prove to be an effective learning material but also show desirable and practical features. The outcomes of the study may help debunk the traditional mindset of dependency on imported finished products and utility power providers. This instructional solar module has several monitoring instruments in that students are able to get actual electrical data that can be applied in real life. We can utilize abundant sunlight in our country by way of making PV solar module power system certainly slashes monthly electric bills without history of roll back. People can start small PV power system up-grade and gradually gain expertise in the art and run all appliances using free energy coming from the environment. Indeed, one practical and doable way we can employ to cut down monthly electric bills is to generate our own power.

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