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Automated Solar Charging Station: An Instructional Mock-Up

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Abstract: The Automated Solar Powered Charging System Device can be charged and located outside of the building and it is environmentally friendly setup. This research developed and designed an automated solar charging station in teaching Elex Tech 111 — Electronic Devices, Instrument and Circuits and the acceptability was evaluated through an instructional mock-up. Quasi-experiment method particularly survey research was employed involving 25 students, 5 instructors of CTU Tuburan Campus, and 10 experts in the said municipality for evaluation. Data were gathered and treated using weighted mean and t-test. From the findings, a conclusion is drawn despite the limitations of the study that included sample size and generalizability. Firstly, the requirements in the construction of the Automated Solar Charging Station included the preparation of the different parts, namely, the right solar panel, charge controller, photovoltaic battery, inverter, electrical load, and solar panel casing safety. These components were assembled following the different processes involved in making electronic products. Secondly, the Effectiveness of the Design and Installation of An Automated Solar Charging Station as an Instructional Mock-up for the respondents was *"Moderately Effective"* as perceived by the respondent groups. It was a helpful innovation, especially during this time of high electricity rates among the consumers of charging stations. Lastly, the output is very economical and practical. Therefore, it is concluded that it meets the standards and is precise functional in performing each functions to be used in instructions and is recommended to be adopted and produced for the utilization of the campus-wide.

Keywords: Technician Education, Automated Solar Charging Station, Instructional Mock-up, Design and Installation, User's Manual, Tuburan, Cebu, Philippines

I. The Problem and Its Scope Introduction

Rationale of the Study

All over the world, people use different electronic gadgets. Technology innovations have put devices in our pockets that we could not have imagined a few years ago. However, these devices often have drawbacks-one of the most pressing issues is with phones, tablets, and laptop PCs to power up. Until now, scientists have built energy sources that are as efficient as our devices.

The current problem is that students on the Cebu Technological University campus when they're doing their research using individual gadgets, and even campus visitors can't charge their own devices.

The automated Solar Powered Charging System Device can be charged and located outside the building and is environmentally friendly. The device stores energy in the photovoltaic battery and converts electricity to the gadgets. It can control overcharged using a microcontroller to prevent explosion (Kondracki, Ryan; Collins, Courtney; Habbab, Khalid, 2014). A microcontroller in the system has the advantage of allowing the system to incorporate a range of functionalities. The system's battery level will be monitored and shown using the microcontroller. Placing the voltage on a seven-segment LCD will ensure enough power to charge the device. Insufficient electricity will prevent the system from being utilized until more power is available. As previously noted, the micro-controller will enable solar efficiency by regulating the solar panel when charging at a time.

The aim of this study is to build an instructional mock-up of a solar charging station that would contribute to the United Nations Sustainable Development Goal Number 7 (Affordable and Clean Energy). This study serves as a stepping stones in creating innovative ways to power up our gadgets instead of relying to electrical based charging system. This will bridge the gap in providing users the best experience, which is user-friendly and accessible for all.

This research will partially answer the problems by developing a Solar Power Charging System device to serve the purpose of electronic gadgets to the students of Cebu Technological University-Tuburan Campus, Tuburan Cebu, Philippines.

II. Theoretical Conceptual Background

The world of making Solar Power Technology from the 7th Century Before Christ to the present is not new. Solar technology started focusing the sun's heat with glass and mirrors to light fires. Today, everything from solar-powered housing to solar-powered cars. The development of solar power technology is speedy, unlike before, was century by century and year by year—the historical development of Solar Power Technology from the 7th Century Before Christ to the 1200s After Death. During the 6th century, the Roman Period, the Hebrew University of Jerusalem built famous large bath houses facing south at the south windows to let the sun's warmth. Sun chambers were so widespread in dwellings and public structures that the Justinian Code established "sun rights" to guarantee each person's access to the sun. By attaching two metal electrodes during his experiment, French scientist Edmond Becquerel found the photovoltaic effect, which generates energy when exposed to light. The University of Delaware researches and develops power using thin-film photovoltaic (PV) and solar thermal systems.

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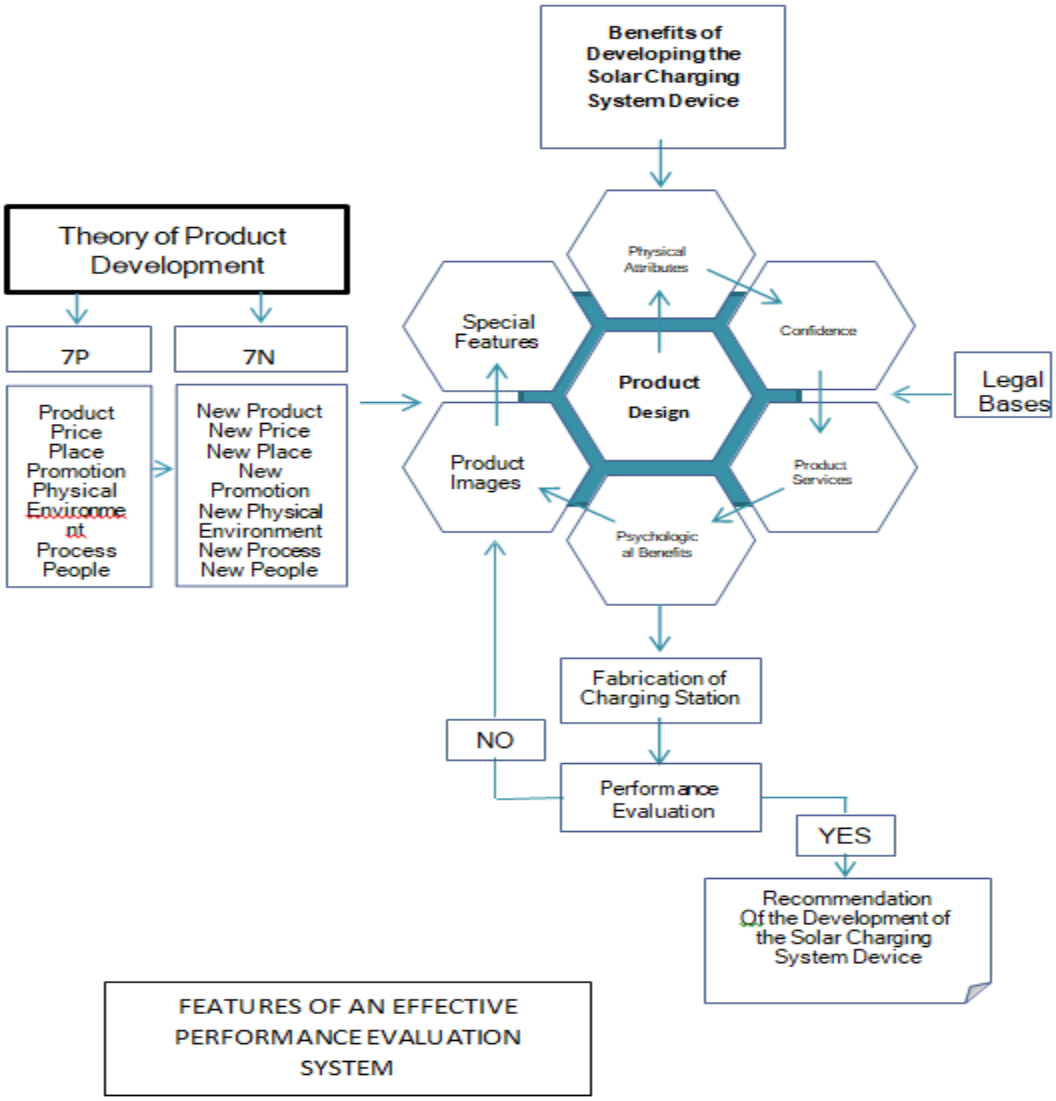

Figure 1 Theoretical and Conceptual Framework of the Study

The University built the so-called" Solar One". It was the world's first photovoltaic (PV) power system for residential. Another study from the US Department of Energy launches the "National Renewable Energy Laboratory" Solar Energy Research Institute". It was the facility dedicated to harnessing power from the sun. In 1983, the total photovoltaic (PV) system produced more than 500 kilowatts. It also used the PV system to provide water pumping and residential electricity in 15 homes when grid power reached the village. Paul Mac Cready invented the solar-powered aircraft and flew it from France to England across the English Channel. The plane had over 16,000 solar cells mounted on its wings, producing 3,000 watts of power.

According to Fojt, the general view about new product development (NPD) is that it brings considerable profits to businesses if the other product is introduced to the market at the right time, is priced at a suitable amount, and targets an appropriate customer group. Fojt questioned the accuracy of this view.

It was stated that NPD could result in net profit or loss. It is advised that the managers should answer various questions before new product decisions to determine whether NPD will bring profit or loss to the business.

Figure 1 illustrates how the Solar Powered Charging System Device was implemented. From the product design that included physical attribution, confidence, product services, psychological benefits, product images, and special features that led to the fabrication of charging station and performance evaluation of the Solar Charging System Device. According to a study conducted by Zhang et al. (2022) that examined the adoption barriers and user experiences of solar- powered electric vehicle (EV) charging stations. Their study found that user acceptance was positively influenced by factors such as system reliability, ease of use, and clear information on energy savings. The research further emphasized the importance of integrating smart technologies, such as IoT, to enhance the charging process's efficiency and user engagement. This study supports the integration of automated systems and smart technologies into solar charging stations to improve adoption rates and user satisfaction.

Furthermore, Kumar and Singh (2023) focused on the design and implementation of an automated solar EV charging system

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integrated with a smart grid. Their findings showed that automation not only enhanced operational efficiency but also optimized energy distribution by dynamically adjusting power flows based on solar availability and grid demand. The study highlighted the crucial role of energy management systems in maximizing the use of solar power and minimizing energy waste, supporting the development of automated systems for solar charging stations in urban environments.

Benefits of Developing the Solar Powered Charging System Device. This device was developed and used for all students on the campus during the study period by charging electronic gadgets while searching for topics and making assignments.

Theory of Product Development. The idea emphasized changing the product quality at less price by adjusting the labor cost, material cost, and improved product quality.

Product Design. The product design introduced the necessary details by reviewing the characteristics of the products, updating the available materials in the market, and other design specifications.

Fabrication of Charging Station. The construction processes of the charging station mixed electronics materials and accessories with an innovative material casing to resist the weather conditions outside of the building area.

Performance Evaluation. The device's performance was highly influential during the product demonstrations by the end users.

Recommendation of the Development of the Solar Charging System Device. Commendation of the device to produce and extend the production to the community and the other universities.

The Problem

Statement of the Problem

This research developed and designed an automated solar charging station in teaching Elex 111 — Electronic Devices, Instrument, and Circuits at Cebu Technological University, Tuburan Campus during Academic Year 2019- 2020 that could be an instructional mock-up.

Specifically, it sought answers to the following questions:

What are the requirements in the construction of the Automated Solar Charging Station: An instructional mock-up to:

1.1. appropriate solar panel;

1.2. charge controller;

1.3. photovoltaic battery;

1.4. inverter;

1.5. electrical load; and

1.6. solar panel casing safety?

What is the performance of the developed instructional mock-up for Elex 111 – Electronic devices, Instrument, and Circuit, as rated by the students, instructors, and experts in terms of the following competencies:

1.7. Identifying the parts and components;

1.8. Assembling the electronic products; and

1.9. Interfacing the circuit connections based on diagrams?

Based on the findings, what instructional guide can be formulated?

Significance of the Study

This study aimed to develop an automated solar charging system: An Instructional Mock-up and determined its effectiveness at Cebu Technological University-Main Campus during the Academic Year 2020-2021. Consequently, the findings of the study will be beneficial to the following:

Instructors. This instructional Mock-up will help them teach the subject Elex 111- Electronic Devices, Instrument, and Circuits in a simplified and innovative way.

Students. By fabricating the device, the students can acquire competencies in using it, enhancing their innovative works.

University. The University benefits from the utilization of the maintenance of the campus.

Industries. This device is viable for industrial use in demonstrating energy saving and consumption efficiency.

The Future Researchers. This study will help other researchers in their future projects for possible collaborations.

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III. Research Methodology

Design of the Study

This study used a Quasi-method of research to gather facts relevant to achieving the discussion details in planning, designing, and fabricating of Design of An Automated Solar Charging Station: An Instructional Mock-up. According to Scribbr, a quasi-experimental method is a design that aims to establish a cause- and-effect relationship between an independent and dependent variable. The normative survey was the mode of acquiring data that used the questionnaire as the main instrument.

Quasi-experimental methods and survey research are the approaches used in the study. The survey questionnaires were given to 5 instructors and 25 students, and ten experts from small-scale Industries for evaluation. Gathered data were treated using total weighted points, weighted mean, and t-test.

Flow of the Study

As shown in Figure 2, this research focused on developing and designing an automated solar charging station that would serve as an instructional mock- up. This study adopted the Input, Process, and Output (IPO) paradigm.

The study began with gathering the requirements for constructing the automated solar charging station, which includes a solar panel, charge controller, photovoltaic battery, inverter, and electrical load. After gathering the construction, the instructor and the students tested the output. The students who received the surveys were interviewed. The student's performance was also studied as one of the inputs of the study.

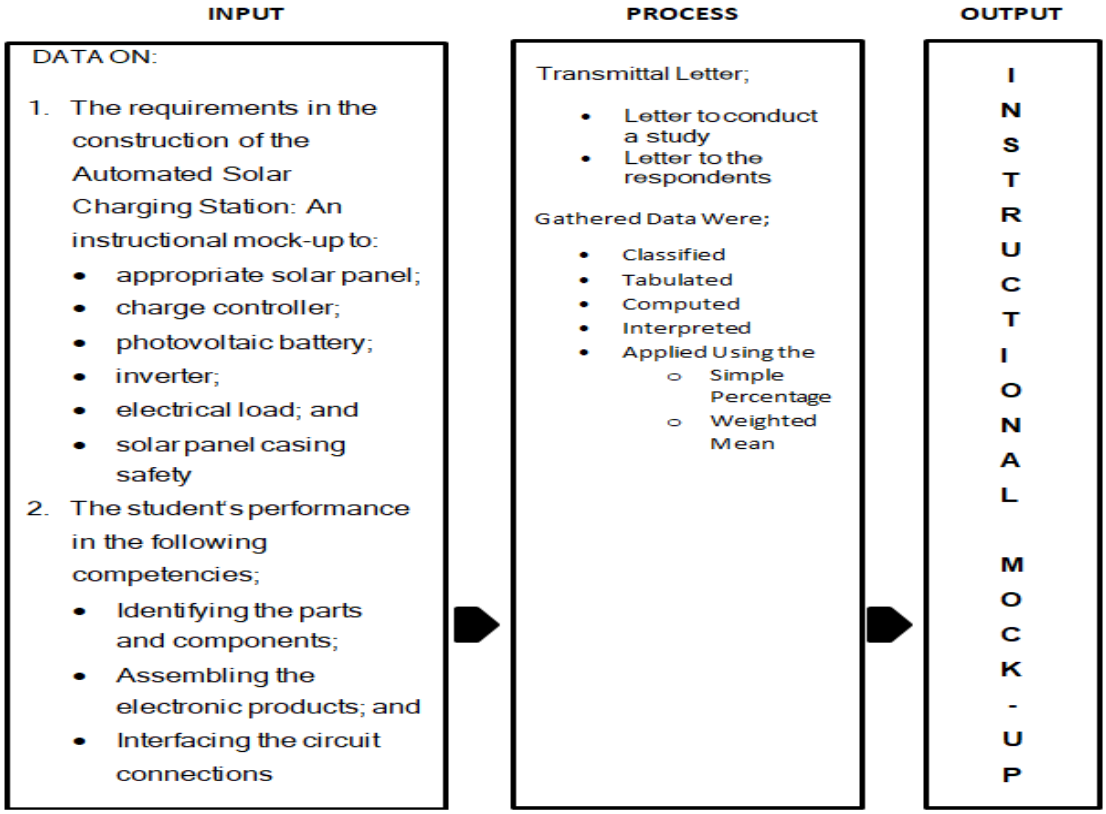

Figure 2 the Flow of the Study

Then, the researcher conducted the tabulation of the gathered data, interpretation and analysis of data or statistical treatment using percentage and ranking as well as a weighted mean to categorize the levels of students' performance.

The process results were the basis for determining the possible output of an Instructional Mock-up.

Environment

The study was conducted at Cebu Technological University Tuburan Campus, Tuburan Cebu. It is one of the ten external campuses of CTU, manned by the newly installed Campus Director, Dr. Ma. Carla Y. Abaquita. This campus is home to more than a thousand students under the Bachelor of Industrial Technology (BIT) taking different majors, namely: automotive technology, computer technology, drafting technology, electrical technology, electronics technology, food preparations and services technology, furniture and cabinet making technology, garments technology, machine shop technology, and welding and fabrication technology.

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The study was conducted specifically on electronics technology. Both the instructors and the students were the respondents to the survey.

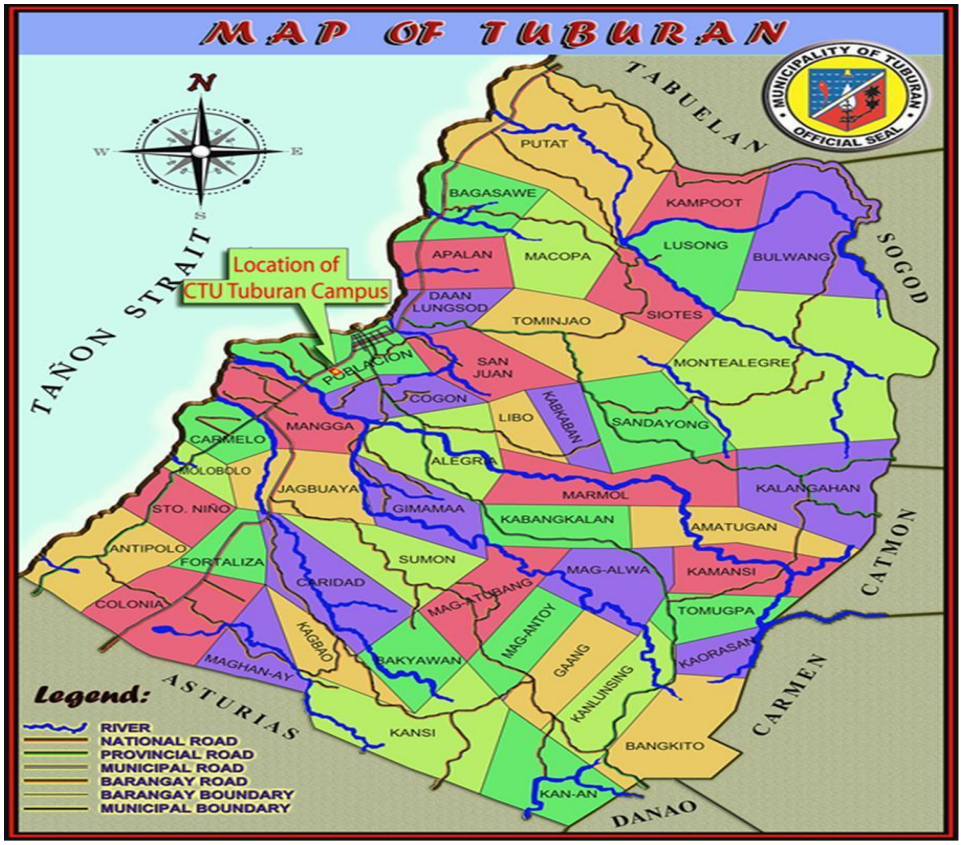

Figure 3 The Research Environment

The researcher has chosen to conduct a study to enhance and ensure continuous improvement of the program and for a possible output that can be useful both in instructions and innovations.

Respondents

The study's respondents were determined by a randomly selected method as a requirement for the intended research. Specifically, it included 25 first-year students in Bachelor of Industrial Technology major in Electronics Technology, five selected Technology faculty of Cebu Technological University – Tuburan Campus, and ten experts from Small Scales Industry to validate the device's effectiveness.

Table 1 Distribution of Respondents N = 40

Respondents	N	Percentage %
Selected Electronics Students	25	63.00
Selected Technology Faculty	5	12.00
Selected Experts from Small Scales Industry	10	25.00
TOTAL	**40**	**100.00**

Instruments

The study utilized a researcher-made questionnaire which was constructed and rated using a five-point Likert scale. The questionnaire was validated using the standard validity instrument with a rating of 4.53, which means the tool is Very High and Valid. The questionnaire was pilot tested on electronics students, instructors, and experts in the Municipality of Tuburan to check its reliability, and it got a rating of 0.879, 0.725, and 0.740 (Cronbach's Alpha), respectively, which means that the items have relatively high internal consistency which implies the instrument is acceptable. The questionnaire has three parts; Part I includes the attributes in terms of identifying features and components; Part II consists of the characteristics of assembling the electronic products; Part III contains the details of Interfacing the Circuit Connections. Users rated how much they agreed with the statements on a scale. It ranges from 1 to 5, wherein five is the highest with a rating of Very Highly effective, four is Highly

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effective, three is Moderately Effective, two is Effective, and one is Not effective. Users' views toward several consumer products were evaluated through the questionnaire. The three respondent groups rated the questionnaire: the students, the instructors, and the experts.

Research Procedures

The research procedure was done according to the following schemes: Preliminary preparation, administration of tests, the gathering of data, and scoring of the test result.

Gathering of data

Preliminary Preparation. The researcher prepared and secured a letter of approval from the University Campus Director of Cebu Technological University. Together with the letter is the researcher-made questionnaire.

Distribution of Questionnaire. The researcher distributed the questionnaire personally to the students, instructors /professors, and experts upon approval. Before filling up the survey questionnaires, an explanation of the purpose of the study and the function of the Design of An Automated Solar Charging Station: An Instructional Mock-up was discussed by the researcher to the end users. After the respondents answered the questionnaires, there were collected by the researcher proximately.

Treatment of data

The data gathered from the survey questionnaire were tallied, collated, tabulated, and subjected to the following statistical treatments.

Weighted Mean. This was used to determine the respondents' perception of the applicability level and the effectiveness of the Design of An Automated Solar Charging Station System: An Instructional Mock-up. A weighted mean is a type of mean that is calculated by multiplying the weight (or probability) associated with a particular event or outcome with its associated quantitative outcome and then summing all the products together (Taylor, 2023).

T-test. This was used to determine the significance of the mean validation on using An Automated Solar Charging Station System: An Instructional Mock-upand its performance, functions, safety, and operations. According to Hayes (2024), a t-test is an inferential statistic used to determine if there is a significant difference between the means of two groups and how they are related.

Scoring Procedure

The average weighted point of the weighted categories was used as the mean of the evaluated item. Thus, the following scoring procedures would provide equal chances for each response category. For the effectiveness of An Automated Solar Charging Station System: An Instructional Mock-up, the following rating scale was used:

Range	Scale	Interpretation	Verbal Description
4.21 – 5.00	5	Very Highly Effective	100% of the performance exceeds the maximum expectations
3.41 – 4.20	4	Highly Effective	95-95% of the performance reaches the maximum expectations
2.61 – 3.40	3	Moderately Effective	85-94% of the performance reaches the average expectations
1.81 – 2.60	2	Effective	75-84% of the performance shows fair expectations
1.00 – 1.80	1	Less Effective	Less than 74% of the performance doesn‘t meet the expectations

Definition of Terms

The following terms used would have a convenient and better understanding of the study:

Approaches. These refer to the strategies and methods of teaching employed by the electrical technology instructors in their respective shop classes.

Attributes. A quality or feature is regarded as a characteristic or inherent part of the output produced in this study.

Benefits. The good points are that the outcomes were beneficial to the recipients of the study.

Characteristics. The salient property of the product, such as efficiency, power, energy-saving feature, and other attributes, serve to identify it.

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Design. The specific layout of the innovative product was the output of this study.

Effectiveness. The degree of acceptance of the recipients is based on their efficiency and use.

Electronics. One of the majors offered by the BIT program specializes in the design, production, installation, testing, service, utilization, and control of electrical and electronic parts, equipment, and systems.

Experts. They are the working professionals in the field of electronics in the Municipality of Tuburan.

Fabrication. Measuring, cutting, bending, and assembling metal to create structures.

Installation. The process of producing the parts and putting them together to form a single output.

Methods. A specific way of doing something or approaching it, especially one that is systematic or established.

Product. Refers to the Instructional Mock-up, which is the output of the study.

Solar Charging Station. An electronics device stores power from the sun and give power to electronic gadgets.

Ethical Considerations

To ensure the greatest degree of professionalism, a letter requesting clearance from the campus president will be processed. An authorized letter will be given to those involved in the study's execution. Informed consent will be given to secure their willingness to participate. The identities of participants will be kept secret at all costs. The obtained records and results will be treated properly, presented, and analyzed. These will only be used to address the issue raised in the study. All information will be kept private. Citations will be used to properly acknowledge and credit sources.

Individual names will be kept hidden from any part of the book to protect the identities of the participants. Individual names will not be required or retained on file during the collection of demographic information. Pseudonyms will be used to identify participants.

Presentation Data, Analysis, and Interpretation

The facts and information collected are presented in this chapter, together with their analysis and interpretation. The study shows the technical requirements of the designed and installed Automated Solar Charging System at Cebu Technological University-Tuburan Campus, Tuburan Cebu, during Academic Year 2019-2020 as the basis for Technology Innovation, particularly in its design, ergonomics, functions, and operation. The perception of the respondent groups towards the performance of the fabricated solar charging station as evaluated by the selected respondent groups as to supply power from the solar system.

The Requirements in the Construction of the Automated Solar Charging Station Instructional Mock-Up

Solar technologies have used photovoltaic (PV) panels or mirrors that focus solar radiation on turning sunlight into electrical energy.

This energy can be used to create electricity or be stored thermally or in batteries

Appropriate Solar Panel

Solar Panels make electricity by enhancing the following steps: STEP 1: Sunlight activates the panels. A rack-and-panel solar system, STEP 2: The cells produce electrical current. A silicon ingot and wafer, STEP 3: The electrical energy is converted, STEP 4: The converted electricity powers your device and gadgets, and STEP 5: A net meter measures usage.

Solar Panel

Figure 4 Solar Panel

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Figure 4 illustrates a solar panel which serves as an integral part of this study. The PV array in the charging station has been designed to facilitate change in tilt angle following the changing seasons, thus facilitating higher irradiation power harnessing. From March till August (our last month of the project), the array was tilted at 10° with the ground and at 40° from October to February.

Charge Controller

Figure 5 Charge Controller

Figure 5 shows the charge controller's which task is to maintain that the system battery is charged while producing electricity to the load.PWM (Pulse Width Modulation) helps regulate the often-inconsistent voltage output by solar panels to protect the system batteries from overcharging. The charge controller is in charge of battery charging, continuously checking the current condition of the storm and self- adjusting to send only the appropriate amount of control to it.

Photovoltaic Cells

The energy produced by the panels that are not immediately required by the load is stored in the battery. This stored energy can either be used during the time of low solar irradiance where the current from the panel is not enough to drive the loads or during the night when solar power is Fig 4: The Solar PV Panels unavailable. The standard type of batteries used here is maintenance- free lead-acid batteries. They are 12V, 20Ah sealed, deep cycle lead-acid rechargeable batteries that are popular for multiple purposes. The batteries use AB plastic shell and valve technology for their protection. It also complies with environmentally friendly requirements. They also usually have a long service life cycle. This type of battery serves two essential purposes in the photovoltaic system: to provide electrical energy generated by the panels whenever the solar panels do not supply the power and to store excess energy generated but the panels whenever the energy exceeds the load. The memory effect is absent from these batteries, meaning there is no need to discharge for the recharging of the batteries. The batteries in the PV system experience a cyclical process of charging and discharging, depending on the presence, absence, or adequacy of sunlight. When the power generated by the panels falls short of the energy required to support the load, charging and discharging cycles occur. The system will be drained and unavailable for use if the battery does not store enough energy to sustain demand during periods without sunlight. If, however, the system is oversized, that is by adding too many battery units and panels, this will be inefficient and expensive at the same time since there will not be enough loads to consume that energy.

Battery

Figure 6 Photovoltaic Battery

Figure 6 shows a photovoltaic battery which is useful in this study. There are three stages to recharging lead acid batteries: 1) charge with a steady current, 2) a bonus charge, and 3). the float charge The constant-current charge applies most of the charge

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and takes about half of the required charge time; the topping charge offers saturation at a reduced charge current, and the float charge compensates for self-discharge loss. The battery is charged to 70% during the constant-current charge, with the remaining 30% filled with the slower topping charge. The topping charge is required for the battery's condition and might be compared to a little break after a satisfying meal. Due to sulphation, the battery will eventually lose its ability to receive a full charge, and its performance will drop. The third stage's float charge keeps the battery fully charged.

Solar Inverter

Figure 7 Inverter

Figure 7 is a solar inverter which converts the variable direct current ('DC') output from your solar panels into alternating 120V/240V current ('AC').

Considering your home's appliances run on AC rather than DC, the solar inverter must convert the DC output gathered by your solar panels.

Electrical Load

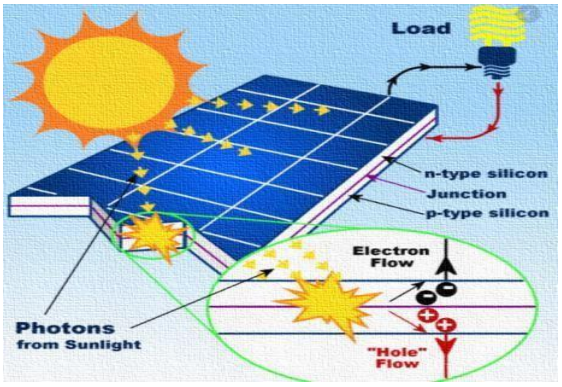

Figure 8 Electrical Load

Figure 8 illustrates an electrical load which serves an integral part of this study. Checking the wattage of your air loads and furnace is imperative. Add only the larger wattage rating to your equation unless you only utilize one at a time. To calculate the number of amps, or the electrical load, divide the corresponding number of watts by volts 220.

Solar Panel Casing Safety

Figure 9 Solar Panel Casing Safety

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Figure 9 illustrates a solar panel casing safety which ensures that all the devices needed for the automated solar charging station mock-up are secure. And it is maintained in good condition by providing a safety tour case that is suitable and movable in any place where the end users are comfortable utilizing the mock -up to achieve competence for the users. The solar panel converts sunlight into DC. A solar regulator supplies this DC to the battery, ensuring it is correctly charged and not destroyed. A solar battery charger can charge batteries without an external power source. You can put this charger in a secure location with plenty of sunlight. Choosing the best charger for needs is advice.

Main Board

Figure 10 Main Board of Solar Charge Controller

Figure 10 shows the main board of the solar charge controller which is a printed circuit board that all circuits and stages of the charge controller are a system that regulates the charging of solar panels and batteries to ensure efficiency in charging, which is to avoid an overcharge of the devices.

Schematic Diagram

A schematic diagram shows the interconnection of circuits and stages to guide and interpret the wiring connection of each electronic component and device of the power inverter. It helps identify the symbols of active and passive members in a circuit.

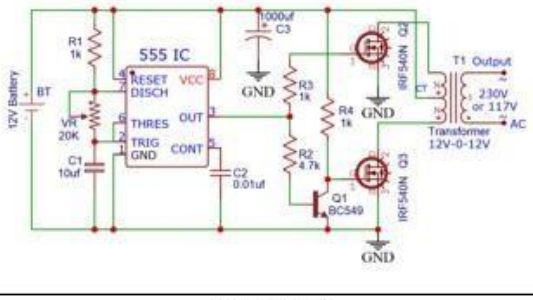

Figure 11
Schematic Diagram of Power Inverter

Figure 11 shows a power inverter which is a critical component in a solar charging system, especially when the system is designed to power AC devices or vehicles.

Wiring Diagram

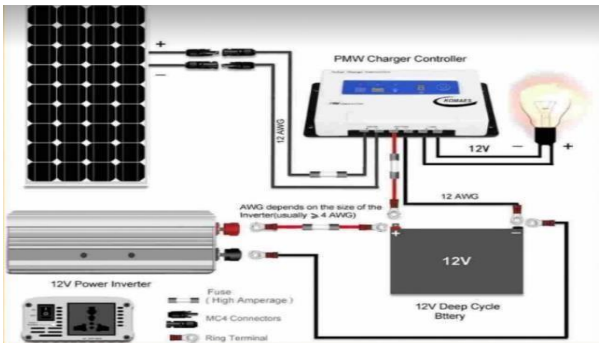

Figure 12 Wiring Diagram

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Figure 12 shows a wiring diagram which is used for an automated solar charging station would illustrate how the various components (solar panels, batteries, charge controllers, inverters, automated charging system, and user interfaces) are connected to work together. The Basics of Solar-Powered Phone Chargers Solar phone chargers produce electricity using small solar panels, which charge your phone's battery, either directly or through your phone, depending on the model.

Micro Controller Block Diagram

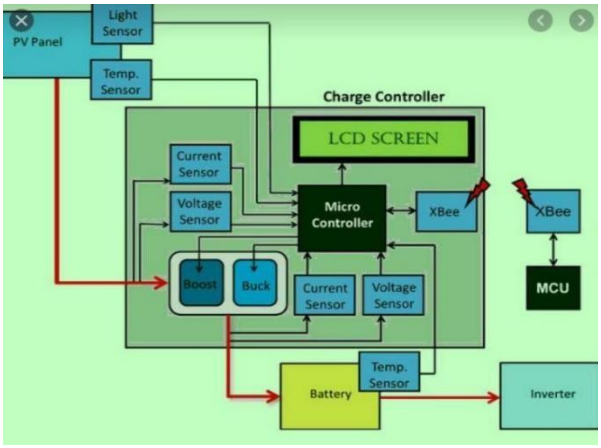

Figure 13 Micro Controller Block Diagram

Figure 13 shows a microcontroller which is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a single chip's processor, memory, and input/output (I/O) peripherals

Triac

Figure 14 Triac

Figure 14 illustrates a TRIAC (Triode for AC) which is a semiconductor device widely used in power control and switching applications. It finds applications in switching, phase control, chopper designs, brilliance control in lamps, fans' speed control, etc.

Performance of the Instructional Mock-Up in the Following Attributes

The performance of the developed instructional mock-up for the solar charging system was based on the competencies based on the program goals. **Identifying the Parts and Components**

Table 2 presents the performance of the developed instructional mock-up in terms of Identifying the Parts and Components.

Table 2 Identifying the Parts and Components N=40

	Students (25)		Instructors (5)		Experts (10)		— X	VD
Attributes	$\bar{x}$	**VD**	$\bar{x}$	**VD**	$\bar{x}$	**VD**		
Solar Panel	3.92	HE	3.36	ME	2.04	E	**3.11**	**ME**
Solar Charge Controller	3.96	HE	3.60	HE	2.04	E	**3.20**	**ME**
Photovoltaic Battery	2.96	ME	3.40	ME	3.42	ME	**3.26**	**ME**

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Power inverter	3.92	HE	3.84	HE	2.80	ME	**3.52**	**HE**
Auto night light switch	3.92	HE	3.84	HE	3.50	HE	**3.75**	**HE**
Led bulb	4.00	HE	3.00	ME	2.10	E	**3.03**	**ME**
Digital dc voltmeter	4.40	VHE	3.72	HE	4.00	HE	**4.04**	**HE**
Banana Plug	4.16	HE	3.72	HE	2.10	E	**3.33**	**ME**
Banana connectors	3.88	HE	3.80	HE	2.10	E	**3.26**	**ME**
Digital ac voltmeter	3.84	HE	3.84	HE	2.75	ME	**3.48**	**HE**
Rocker switch	4.04	VHE	3.08	ME	2.75	ME	**3.29**	**ME**
Light-dependent resistor	3.88	HE	3.32	ME	4.00	HE	**3.73**	**HE**
Fixed resistor	4.08	VHE	3.32	ME	2.67	ME	**3.36**	**ME**
Polarized capacitor	3.92	HE	3.84	HE	1.84	E	**3.20**	**ME**
Trimmer	3.96	HE	3.80	HE	3.66	HE	**3.81**	**HE**
Triac	4.08	HE	3.80	HE	1.92	E	**3.27**	**ME**
Bridge diode	4.08	HE	3.00	ME	3.50	HE	**3.53**	**HE**
Ceramic	3.88	HE	3.72	HE	2.67	ME	**3.42**	**HE**
Signal diode	3.92	HE	3.64	HE	2.10	E	**3.22**	**ME**
Switching transistor	3.92	HE	3.92	HE	1.94	E	**3.26**	**ME**
Printed circuit board	4.00	HE	3.64	HE	3.66	HE	**3.77**	**HE**
Total weighted mean:	**3.94**	**HE**	**3.58**	**HE**	**2.74**	**ME**	**3.42**	**HE**

Legends: 4.21 – 5.00 Very Highly Effective (VHE)

3.41 – 4.20 Highly Effective (HE)

2.61 – 3.40 Moderately Effective

1.81 – 2.60 Effective (E)

1.00 – 1.80 Less Effective (LE)

It shows that twenty-one electronic components of the device were used for the study's development. Based on the results rated by the students after the demonstration, the majority or seventeen (17) parts and components were “Highly Effective”; three (3) were rated as “Very Highly Effective”; and only one was rated as “Moderately Effective”. Hence, the total weighted mean is 3.94 with the verbal description of “Highly Effective”. Some received lower rating like Banana Plug due to its compatibility measures that made it less effective compared to other components.

The responses of instructor respondents teaching the major field of specialization disclosed that none of those mentioned above was rated as "Highly Effective,"; yet the majority of fourteen (14) of the identified parts and components were rated as "Highly Effective”. On the other hand, further shown are the ratings of expert respondents, wherein the majority or nine (9) parts and components were rated as “Effective”; and six (6) were “Highly Effective” and “Moderately Effectively”, respectively.

With this, the overall weighted mean is 3.42 with a verbal description of “Highly Effective”. It means that the electronic components that comprised the automated solar charging station highly contribute to the overall performance during the laboratory mock-up. The study was instrumental and adequate for the students and community. However, according to the study by Kharchenko (2015), there are hidden defects, counterfeit parts, and components with incompatible construction materials with both internal and external service conditions in electronic components and devices that should be observed through final testing before installation.

Assembling the Electronic Products

Table 3 presents the effectiveness of assembling the electronic products based on the processes undertaken.

The Table enumerates the twenty (20) processes in sequential order involved in assembling the electronic products with the corresponding ratings by the respondents on their effectiveness. The majority of seventeen (17) of the

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Table 3 Assembling the Electronic Products N=40

	Students (25)		Instructors (5)		Experts (10)		$\bar{X}$	VD
Processes	$\bar{x}$	**VD**	$\bar{x}$	**VD**	$\bar{x}$	**VD**		
1. Preparing the materials needed for instructional mock-up	3.76	HE	3.30	ME	3.40	ME	**3.49**	**ME**
2. Making a design of the printed circuit board based on their schematic diagram	3.70	HE	3.64	HE	3.10	ME	**3.48**	**HE**
3. Cutting printed circuit board in sizes according to its dimensions	2.80	ME	3.44	ME	2.75	ME	**3.00**	**ME**
4. Making a pattern of the schematic diagram into PCB design	2.88	HE	3.76	HE	2.75	ME	**3.13**	**ME**
5. Printing out in a mirror pattern for exact design	3.90	HE	3.80	HE	2.61	ME	**3.44**	**HE**
6. Putting onto the copper clad of the printed circuit board	3.95	HE	3.82	HE	3.50	HE	**3.76**	**HE**
7. Applying the heat transfer method using an electric iron to a maximum level of heat	4.10	HE	3.10	ME	3.45	HE	**3.55**	**HE**
8. Removing the photo paper after heating the PCB	4.44	VHE	3.80	HE	3.30	ME	**3.85**	**HE**
9. Letting the PCB warm and getting a plastic basin, then applying a liquid solution	4.10	HE	3.82	HE	3.50	HE	**3.81**	**HE**
10. Preparing agua oxide and muriatic acid with ration 1:1 composition	3.86	HE	3.80	HE	3.65	HE	**3.77**	**HE**
11. Monitoring the PCB when etching for a good result	3.80	HE	3.80	HE	3.90	HE	**3.83**	**HE**
12. Washing the PCB with clean water to avoid corrosion	4.10	HE	3.10	ME	3.00	ME	**3.40**	**ME**
13. Cleaning the copper side with lacquer thinner	3.82	HE	3.30	ME	2.75	ME	**3.29**	**ME**
14. Boring the identified holes for mounting the electric components	4.08	VHE	3.32	ME	3.50	HE	**3.63**	**HE**
15. Applying sandpaper to the copper side with a required number of 1000	3.88	HE	3.80	HE	4.25	VHE	**3.98**	**HE**
16. Preparing the components for mounting into the holes	3.90	HE	3.84	HE	3.80	HE	**3.85**	**HE**
17. Soldering the components of 30 watts at the correct melting point	4.10	HE	3.80	HE	3.50	HE	**3.80**	**HE**
18. Applying clear varnish to prevent corrosion of the PCB	4.08	HE	3.10	ME	4.20	HE	**3.79**	**HE**
19. Testing the actual output of its functionalities	3.86	HE	3.68	HE	3.41	HE	**3.65**	**HE**
20. Calibrating the trimmer for the sensitivity of the resistor and load	3.90	HE	3.80	HE	4.20	HE	**3.97**	**HE**
Total weighted mean:	**3.85**	**HE**	**3.59**	**HE**	**3.43**	**HE**	**3.62**	**HE**

Legends: 4.21 – 5.00 Very Highly Effective (VHE)

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1.81 – 2.60 Effective (E)

3.41 – 4.20 Highly Effective (HE)

1.00 – 1.80 Less Effective (LE)

2.61 – 3.40 Moderately Effective

processes involved had rated by the students as "Highly Effective"; two (2) were rated as "Very Highly Effective"; and only one (1) was "Moderately Effective". Hence, the total weighted mean is 3.85 with a verbal description of "Highly Effective".

This implies that the tasks involved in assembling the electronic products are executable in the part of the students.

With regards to the instructors' ratings, thirteen (13) of the processes involved were rated as "Highly Effective"; and seven (7) were rated as "Moderately Effective". Hence, the total weighted mean is 3.59 with a verbal description of "Highly Effective".

The results suggest that the processes in making the electronic products are still performable by the instructors. It was gleaned in the study that the instructors had rated "More Moderatley Effective" all the processes in the study compare to the students, this is due to some of the respondents have individual level of performance in assembling the electronic products.

Similarly, the majority of eleven (11) of the above processes were "Highly Effective" as rated by the experts; eight (8) were rated as "Moderately Effective"; and one (1) had a "Very Highly Effective" rating. Hence, the total weighted mean is 3.43 with a verbal description of "Highly Effective".

This implies that all processes involved in assembling electronic products that were rated by the students and instructors as "Highly Effective" were thoroughly validated by an experts, since they have similar results in the study as they followed the processes in assembling the electronic products.

To sum up, the overall weighted mean of the processes involved in assembling the electronic product is 3.62 with a verbal description of "Highly Effective," wherein the majority or fifteen (15) of the operations were rated by the respondents as "Highly Effective" and five (5) were "Moderately Effective".

I that automated solar charging station design is assembled effectively following the systematic and standard procedures in creating the electronic product. It implies that this electronic product is fully functional, which would contribute to its overall performance. The practical application of following the processes of assembling an electronic product by the students is the most effective tool for measuring the concept learned in all fields other than Electronics Technology (Diola, 2019). It supports the theory of "Learning by Doing" by John Dewey that a hands-on approach to learning is essential for the students to adapt and learn.

Interfacing the Circuit Connections

Table 4 presents the effectiveness of the attributes in Interfacing the Circuit Connections based on the diagram.

Table 4 Interfacing the Circuit Connections N=40

	Students (25)		Instructors (5)		Experts (10)			
Attributes	$\bar{x}$	**VD**	$\bar{x}$	**VD**	$\bar{x}$	**VD**	**_ X**	**VD**
Solar panel to the solar charge controller	4.16	HE	4.12	HE	4.18	HE	**4.15**	**HE**
Solar charge controller to the battery	3.20	ME	4.12	HE	4.20	HE	**3.84**	**HE**
Battery to the power inverter	4.24	VHE	4.24	VHE	3.38	HE	**3.95**	**HE**
Power inverter to load.	4.20	HE	4.16	HE	2.12	E	**3.49**	**HE**
Power inverter to auto night light switch	4.24	VHE	4.28	VHE	3.35	ME	**3.96**	**HE**
Complete wiring connection with load ports	4.76	VHE	4.32	VHE	2.14	E	**3.74**	**HE**
Testing the loads	4.32	VHE	4.36	VHE	4.15	HE	**4.28**	**VHE**
Total weighted mean	**4.16**	**HE**	**4.23**	**VHE**	**3.36**	**ME**	**3.92**	**HE**

Legends: 4.21 – 5.00 Very Highly Effective (VHE)

3.41 – 4.20 Highly Effective (HE)

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2.61 – 3.40 Moderately Effective

1.81 – 2.60 Effective (E)

1.00 – 1.80 Less Effective (LE)

The Table above presents seven (7) attributes of Interfacing the Circuit Connections' effectiveness as rated by the students, instructors, and experts following the diagram after the demonstration. Out of seven (7) attributes, four (4) of them were rated by the students as "Very Highly Effective"; two (2) were rated as "Highly Effective," and only one (1) attribute was rated as "Moderately Effective". With this, the overall weighted mean is 4.16 with a verbal description of "Highly Effective"**.**

It was found out in the study that the attributes in interfacing circuit connections were rated by the students as "highly effective" since they were relied based on the suggested given pattern. The results suggest that when interfacing circuit connections was rated by the students as "highly effective" because some of them have only limited knowledge so that more appreciations they will rate what has been guided.

Further shown are also the instructors 'ratings wherein four (4) processes were rated as "Very Highly Effective" and the rest were "Highly Effective". Therefore, the total weighted mean is 4.23 with a verbal description of "Very Highly Effective".

The same with the instructors, it was revealed in the study that interfacing circuit connections were Highly Effective since. This implies that most of them were agreeable the attributes encompassing circuit connections interface.

In contrast, the experts' responses on the effectiveness of interfacing the circuit connections, reveals that four (4) processes were rated as "Highly Effective"; one (1) was "Moderately Effective," and only two (2) were "Effective". Therefore, the total weighted mean is 3.36 with a verbal description of "Moderately Effective".

Although, the three (3) respondents; students, instructors and experts have total rating of "Highly Effective", it was also gleaned in the study that out of the three respondents, only experts respondents have rated only lesser value because they are more knowledgeable compare to the students and instructors. This means that the experts may accept or may contribute knowledge in developing attributes in interfacing circuit connections.

Hence, the data reveal that the overall weighted mean is 3.92 with a verbal description of "Highly Effective," wherein Testing the Loads was found as a very highly effective process; and the rest processes are highly effective in interfacing the circuit connections. It means that interfacing the circuit connections is systematic and should be observed correctly in harnessing the gadgets and equipment. However, there should be a consideration of the polarity to prevent short circuit connection. It implies that this study was instrumental and influential in interfacing the circuit connections of the device. According to Khamisani (2018), the off-grid bus shelter project will solely rely on solar energy, with solar photovoltaics generating electricity to power electronics gadgets.

Summary of the performance in using the Instructional Mock-up

Table 5 presents the summary of the performance in using the constructed mock-up.

Table 5 Summary of the performance in using the Instructional Mock-up N=40

	Students (25)		Instructors (5)		Experts (10)			
Identifying the parts and components	3.94	HE	3.58	HE	2.74	ME	**3.42**	**ME**
Assembling the Electronic Products	3.85	HE	3.59	HE	3.43	HE	**3.62**	**HE**
Interfacing the circuit connections based on diagrams	4.16	HE	4.23	VHE	3.36	ME	**3.92**	**HE**
Total Weighted Mean	**3.98**	**HE**	**3.80**	**HE**	**3.18**	**ME**	**3.65**	**HE**

Legends: 4.21 – 5.00 Very Highly Effective (VHE)

3.41 – 4.20 Highly Effective (HE)

2.61 – 3.40 Moderately Effective

1.81 – 2.60 Effective (E)

1.00 – 1.80 Less Effective (LE)

The Table discloses the performance summary using the instructional mock-up according to the results revealed in the data mentioned earlier. All attributes that comprised the developed automated solar charging station were rated as "Highly Effective" by the students' respondents during the instructional mock-up having a total weighted mean of 3.98 with the verbal description of "Highly Effective". As to the summary of instructors' responses, *Interfacing the circuit connections based on diagrams* was "Very

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Highly Effective," and the rest were "Highly Effective", therefore the total weighted mean is 3.80 or "Highly Effective". On the other hand, according to the experts' summary of responses, *Assembling the Electronic Product* has the highest weighted mean with a rating of "Highly Effective," and the rest attributes were "Moderately Effective", therefore the total weighted mean is 3.18 with a verbal description of "Moderately Effective".

Hence, the overall weighted mean of the performance summary using the Instructional Mock-up is 3.65, with a verbal description of "Highly Effective". Wherein according to the responses of the group respondents, *Interfacing the circuit connections based on diagrams* and *Assembling the Electronic Products* was "Highly Effective" with an overall weighted mean of 3.92 and 3.62, respectively, whereas *Identifying the parts and components* has the overall weighted mean of 3.42 verbally described as "Moderately Effective". The developed automated solar charging station is a very effective instructional resource in teaching the subject Elex 111 (Electronic Circuit, Device, and Instruments) to transfer knowledge and skills to the Electronics Technology students successfully. It implies that this electronic product is a big help to the end users to adopt and practice fabrication and to install the device to develop the skills and practice all competencies acquired on the device as a model technology. According to Linguete (2019), the use of instructional mock-ups in delivering the instructions in Electronics will help the students become more accustomed current industry setup and enhance their technological skills; thus, there is a smooth transition from the institution to industry. It supported the study of Adalikwu and Iorkpilgh (2013) that using instructional materials enhances students' understanding of the theories and concepts, thus performing significantly better.

IV. Summary, Findings, Conclusion, and Recommendation

This chapter presents the summary of the study, its findings, conclusion, and recommendations based on the results and interpretation of data from the previous chapter. It also offers the performance, functions, and operations of An Automated Solar Charging Station as an Instructional Mock-up that serves as equipment to supply energy. The study aimed to develop and design an Automated Solar Charging Station: An Instructional Mock-up that can be used for BIT Electronics Technology students teaching the subject, Elex 111.

Summary

The study designed an automated solar charging station as an instructional mock-up. The scope of the study included the preparation of the different parts, namely, the right solar panel, charge controller, photovoltaic battery, inverter, electrical load, and solar panel casing safety. These components were assembled following the different processes involved in making electronic products. The selected electronics students, instructors, and experts tested the performance of the produced product. The Quasi-experimental methods of careful survey research were employed in this study. Questionnaires were given to 5 instructors and 25 students and ten experts from small-scale industries for evaluation. Gathered data were treated using total weighted points, weighted mean, and T-test.

Findings

The following are the essential findings of the study:

1. In developing and designing the automated solar charging station, there's a need to gather all the parts before assembling it, and the use of appropriate features and components was a significant consideration;
2. It revealed that of the three performance competencies of the automated solar charging station, the respondents perceived that identifying the parts and components and the assembling of electronics products was Moderately Effective, while interfacing the Circuit Connections was Highly Effective; and
3. Measures would enhance the product's efficiency and functionalities.

Conclusion

From the findings, a conclusion is drawn despite the limitations of the study that included sample size and generalizability. Firstly, the requirements in the construction of the Automated Solar Charging Station included the preparation of the different parts, namely, the right solar panel, charge controller, photovoltaic battery, inverter, electrical load, and solar panel casing safety. These components were assembled following the different processes involved in making electronic products. Secondly, the Effectiveness of the Design and Installation of An Automated Solar Charging Station as an Instructional Mock-up for the respondents was ***"Moderately Effective"*** as perceived by the respondent groups. It was a helpful innovation, especially during this time of high electricity rates among the consumers of charging stations. Lastly, the output is very economical and practical. Therefore, the Elex 111 instructors can use this output to enhance instruction that can be improved and modified depending on the user's comfortability.

Recommendations

It is recommended that the An Automated Solar Charging Station: An Instructional Mock-up be adapted and produced for campus-wide utilization.

1. It is recommended for students to have simulations using the mock-up to ensure maximum hands-on activity guides that

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are active and integrated.

2. It is recommended for instructors to utilize this mock-up to enhance instructions in the teaching of Elex 111 that is more collaborative and meaningful.
3. It is recommended for administrators to ensure that research-based creative outputs must be recognized and emphasized in instruction.
4. It is also recommended to conduct pilot tests across other campuses to validate scalability and for future researches to test the systems in varied environmental conditions.

Acknowledgement

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He expresses a gratitude to his family members for their inspiring support. Firstly, to his loving wife and children for invaluable assistance in terms of moral support for giving the strength and inspiration to his life.

To all the persons who in one way or another help me a lot, no philosophical words can be best but at least allow me to say **Thank You Very Much.**

V.H.PATINDOL

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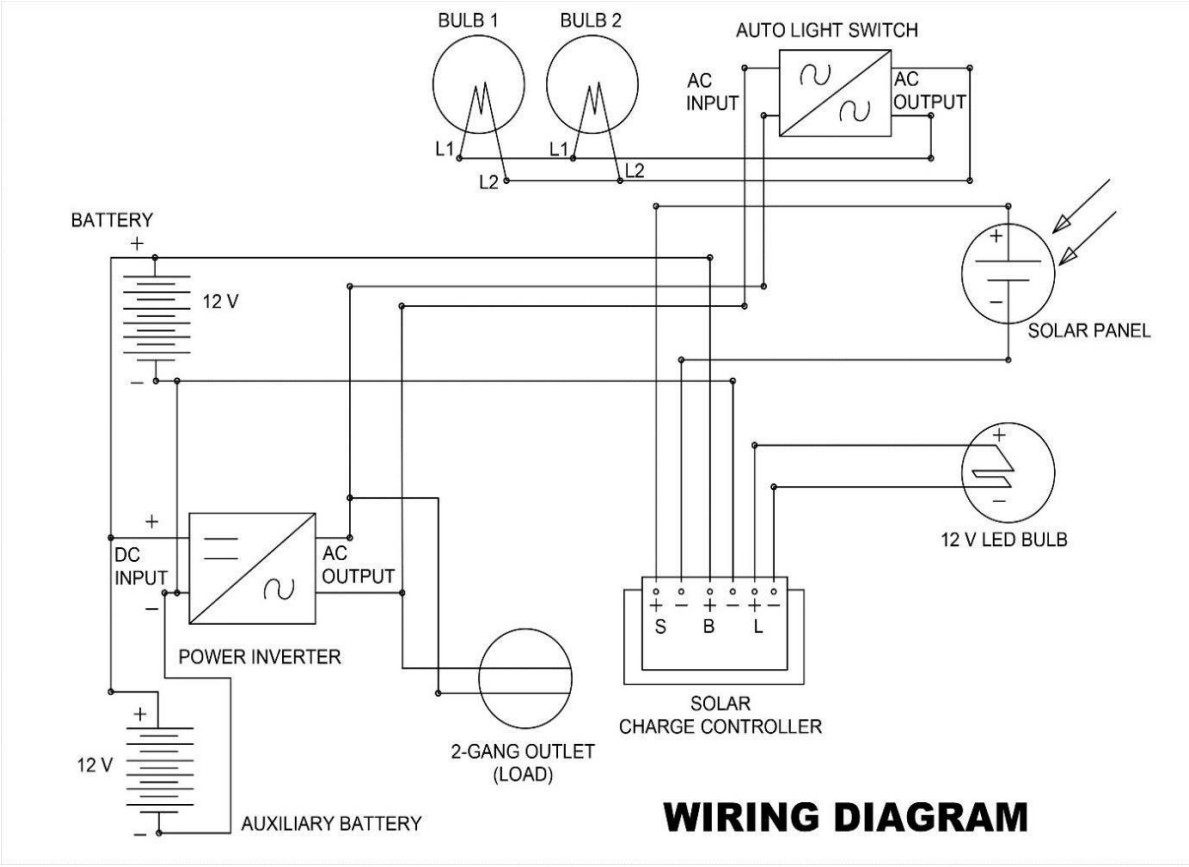
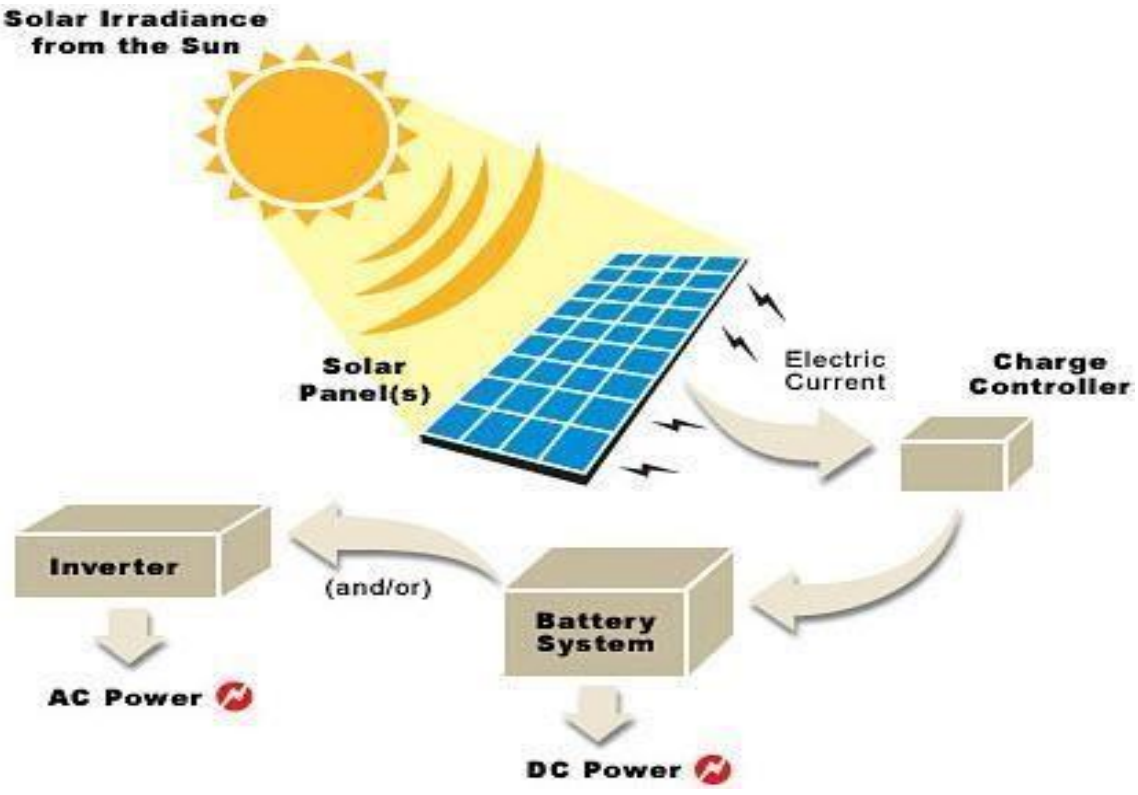
APPENDICES

Appendix A Wiring Diagram



Appendix B Block Diagram



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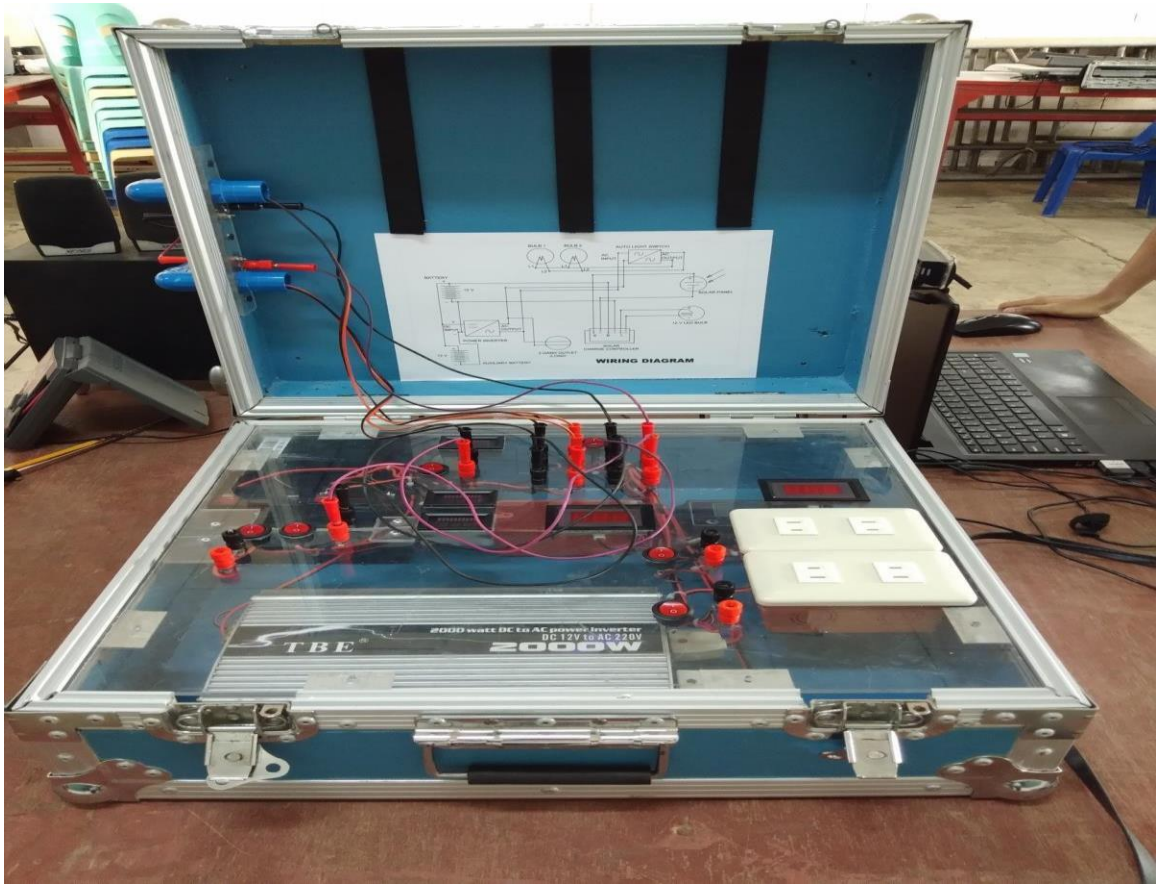
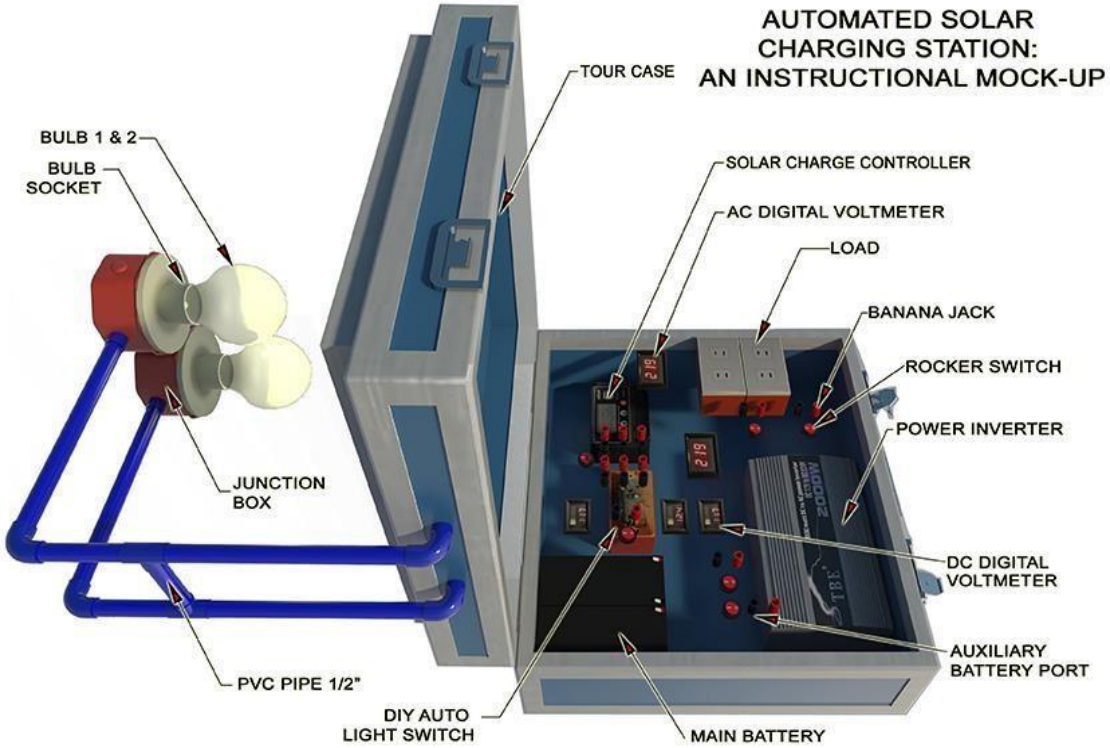
Appendix C

Automated Solar Charging Station Mock-Up



Appendix D



Automated Solar Charging Station Mock-Up Parts Labeled

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Appendix E

Letter to Conduct a Study

DR. MA. CARLA Y. ABAQUITA

Campus Director

Cebu Technological University Tuburan Campus

Madam:

The undersigned is conducting a study entitled, _‘ Automated Solar Charging Station: An Instructional Mock-up‘‘ as a requirement of the degree, Master in Technician Education. This study aims to assess the performance of the automated solar charging station instructional mock up in teaching Elex 111- Electronic Devices, Instrument and Circuit at Cebu Technological University, Tuburan Campus during Academic Year 2019-2020 that can be used as an instructional mock-up.

With this, I would like to ask for your approval to conduct my study to the respondents particularly the students and instructors in the Elex 111- Electronics Devices, Instrument and Circuit Subject of the College of Technology, BIT Department. Rest assured that, classes will not be interrupted during the conduct of the study as in is being coordinated by the subject instructors.

Your positive response on this matter will bring not only the success of this study but a great milsetone of my journey in my Master‘s Degree. I am thanking you in advance for the approval of this request.

Sincerely yours,

VICTORINO H. PATINDOL

Researcher

Approved:

MA. CARLA Y. ABAQUITA, RChe., Dev. Ed. D.

Campus Director

Appendix F

Letter to the Respondents

Dear respondents,

The undersigned is conducting a study entitled, _‘ Automated Solar Charging Station: An Instructional Mock-up‘‘ as a requirement of the degree, Master in Technician Education. This study aims to assess the performance of the automated solar charging station instructional mock up in teaching Elex 111- Electronic Devices, Instrument and Circuit at Cebu Technological University, Tuburan Campus during Academic Year 2019-2020 that can be used as an instructional mock-up.

In order to make this research worthwhile and efficient, the researcher humbly asks for your participation in a voluntary nature. Only academic purposes will be served by the information gathered. You can assure that the data you provide will be kept confidentially.

The researcher hopes for your positive cooperation.

Sincerely yours,

VICTORINO H. PATINDOL

Researcher

Appendix G Survey Questionnaire

Name (Optional): _____

This questionnaire is designed to assess the performance of the automated solar charging station instructional mock up in teaching Elex 111- Electronic Devices, Instrument and Circuit at Cebu Technological University, Tuburan Campus during Academic Year 2019-2020 that can be used as an instruction al mock-up. Please take some time to answer this questionnaire. Rest assured that the information you share will be treated with utmost confidentiality, while observing the ethical standards of research. Thank you so much for your time and cooperation.

Are you a/an?

_____Student

_____Instructor

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Expert

Part I: Identifying Parts and Components

Instructions: Please put a check on the space provided based on your perception towards the performance of the automated solar charging station instructional mock-up as to its parts and componets. Use the following scoring procedure for your reference.

5 Very Highly Effective

4 Highly Effective

3 Moderately Effective

2 Effective

1 Not Effective

Attributes	Very Highly effective (5)	Highly Effective (4)	Moderately Effective (3)	Effective (2)	Not Effective (1)
Solar Panel					
Solar Charge Controller					
Photovoltaic Battery					
Power inverter					
Auto night light switch					
Led bulb					
Digital dc voltmeter					
Banana Plug					
Banana connectors					
Digital ac voltmeter					
Rocker switch					
Light dependent resistor					
Fixed resistor					
Polarized capacitor					
Trimmer					
Triac					
Bridge diode					
Ceramic					
Signal diode					
Switching transistor					
Printed circuit board					

Part II: Assembling the Electronic Product

Instructions: Please put a check on the space provided based on your perception towards the performance of the automated solar charging station instructional mock-up as to assembling the electronic product. Use the following scoring procedure for your reference.

5 Very Highly Effective

4 Highly Effective

3 Moderately Effective

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2 Effective

1 Not Effective

Attributes	Very Highly effective (5)	Highly Effective (4)	Moderately Effective (3)	Effective (2)	Not Effective (1)
1.Preparing the materials needed for instructional mock-up					
2.Making a design of the printed circuit board based on their schematic diagram					
3.Cutting printed circuit board in sizes according to its dimensions					
4.Making a pattern of the schematic diagram into PCB design					
5.Printing out in a mirror pattern for exact design					
6.Putting onto the copper clad of the printed circuit board					
7.Applying heat transfer method using electric iron into a maximum level of heat					
8.Removing the photo paper after heating the PCB					
9.Letting the PCB warm and getting a plastic basin then applying liquid solution					
10.Preparing agua oxide and muriatic acid with ration 1:1 composition					
11.Monitoring the PCB when etching for good result					
12.Washing the PCB with clean water to avoid corrosion					
13.Cleaning the copper side with lacquer thinner					
14.Boring the identified holes for mounting the electric components					
15.Applying sand paper into the copper side with required number of 1000					
16.Preparing the components for mounting into the holes					
17.Soldering the components of 30 watts in correct melting point					
18.Applying clear varnish to prevent corrosion of the PCB					
19.Testing the actual output of its functionalities					
20.Calibrating the trimmer for the sensitivity of the resistor and load					

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Part III: Interfacing the Circuit Connections

Instructions: Please put a check on the space provided based on your perception towards the performance of the automated solar charging station intructional mock-up as to interfacing the circuit connections. Use the following scoring procedure for your reference.

5 Very Highly Effective

4 Highly Effective

3 Moderately Effective

2 Effective

1 Not Effective

Attributes	Very Highly effective (5)	Highly Effective (4)	Moderately Effective (3)	Effective (2)	Not Effective (1)
Solar panel to solar charge controller.					
Solar charge controllerto battery.					
Battery to power inverter.					
Power inverter to load.					
Power inverter to auto night light switch.					
Complete wiring connection with load ports.					
Testing the loads.					

-end of the questionnaire-