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Review Article

Promoting Renewable Energy Education to Middle School and High School Students Through Sponsored Summer Camps

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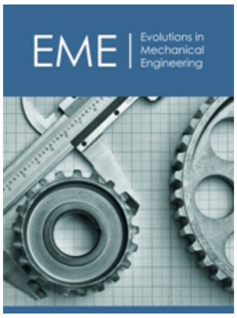

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Abstract

This project describes the effort made to train middle school and high school students about renewable energy, especially solar and wind energy through a sponsored summer camp. Modules are developed over two consecutive years to demonstrate and provide hands-on experience on the working principle of solar cells, automatic direction changing of a solar panel by tracking sunlight with a dual-axis tracker, gathering wind and solar data to commission solar cells and wind turbines, building a circuit and measuring Voltage-Current (V-I) characteristic to analyze the performance of solar cells and working principle of a Die-Sensitized Solar Cell (DSSC). This paper evaluates the effectiveness of the summer camp in promoting renewable energy and engineering as well as increasing their interest in these fields as careers. The analysis based on the survey conducted explores strategies and provides guidelines for designing future camps that may enhance the effectiveness of the summer camp outcomes.

Keywords: Renewable energy education; Summer camp; Arduino; Die-sensitized solar cell; Wind data; Solar data

Introduction

The world is currently highly dependent on fossil fuels, such as oil, coal and natural gas, as primary sources of energy, with relatively inadequate use of renewable energy. Burning fossil fuels releases substantial amounts of greenhouse gases, for instance, Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) into the atmosphere that has to be reduced to address climate change [1]. Fossil fuel combustion is responsible for about 78% of the total global greenhouse gas emissions increased between 1970 and 2010 thus changing the climate [2]. It was estimated that there would be a significant rise in greenhouse gas emissions if the world failed to initiate proper policy initiatives for reducing the combustion of fossil fuels [3]. The current CO_2 level in the atmosphere is 420 parts per million on average, which is 50% higher than before the Industrial Revolution. Nearly all countries agreed to address climate change with an added goal of reducing global temperature by 1.5 °C through the Paris climate agreement [4]. Many countries already have taken initiatives: Argentina to reduce the use of fossil fuels, Brazil to utilize 100% CO_2-free new vehicles, China to eliminate coal-fired plants, The European Union, India, Japan and the USA to introduce zero-emission cars [5]. Energy consumption, carbon emissions, and economic growth have been investigated between renewables and non-renewable energy sources in China using 60 years of data from 1952 to 2012 [6].

Renewable energy sources include solar radiation, wind power, hydroelectricity, geothermal energy and biomass. Through the utilization of renewable energy technologies, these sources are converted into practical forms of energy, predominantly electricity, but also including heat, chemicals, or mechanical power (as of September 3, 2023, National Renewable Energy Laboratory-NREL website). Renewable energy sources, e.g., solar, biomass, wind, hydro and geothermal, can be an alternative to fossil fuels for decreasing greenhouse gas emissions. Figure 1 shows the allocation of power generation from different sources which indicates only 20% electricity is generated from renewable energy resources (9.2% wind, 2.8% photovoltaic (PV) solar, 0.1% solar thermal and a few other sources such as hydropower), whereas 61% was from fossil fuel and 19% from nuclear energy totaling about 4,116 billion kilowatt-hours (kWh) (or about 4.12 trillion kWh) of electricity in the United States (as of September 3, 2023, United States (US) Energy Information Administration (EIA) website). According to the International Renewable Energy Agency (IRENA), renewable energy has the potential to supply 90 percent of the world's electricity by 2050 (as of September 3, 2023, International Renewable Energy Agency (IRENA) website). Also, by the year 2050, it is projected that renewable energy sources could achieve a decarbonization rate of 90 percent in the global power sector. Renewable energy led by wind and solar energy has become a potential source of global power supply because these are clean, renewable and abundant in nature. Also, PV solar and wind energy are now increasingly becoming the least expensive energy sources in the global market. Solar panels generate 90% less pollution than traditional coal-based electricity production. Coal-based electric plants require high levels of water for cooling and steam generation while solar panels require 99% less water than coal power plants [6]. There are two major types of solar energy technologies such as Photovoltaics (PV) and Concentrating Solar Power (CSP) converting solar radiation to electricity directly [7]. A few other ways are available to utilize solar energy such as passive solar technology to provide light and heat to warm houses, water and processes. However, the photovoltaic system contributes the most, and approximately 49 billion kWh of electricity generation was generated using small-scale solar photovoltaic systems in 2021 (United States (US) Energy Information Administration (EIA)).

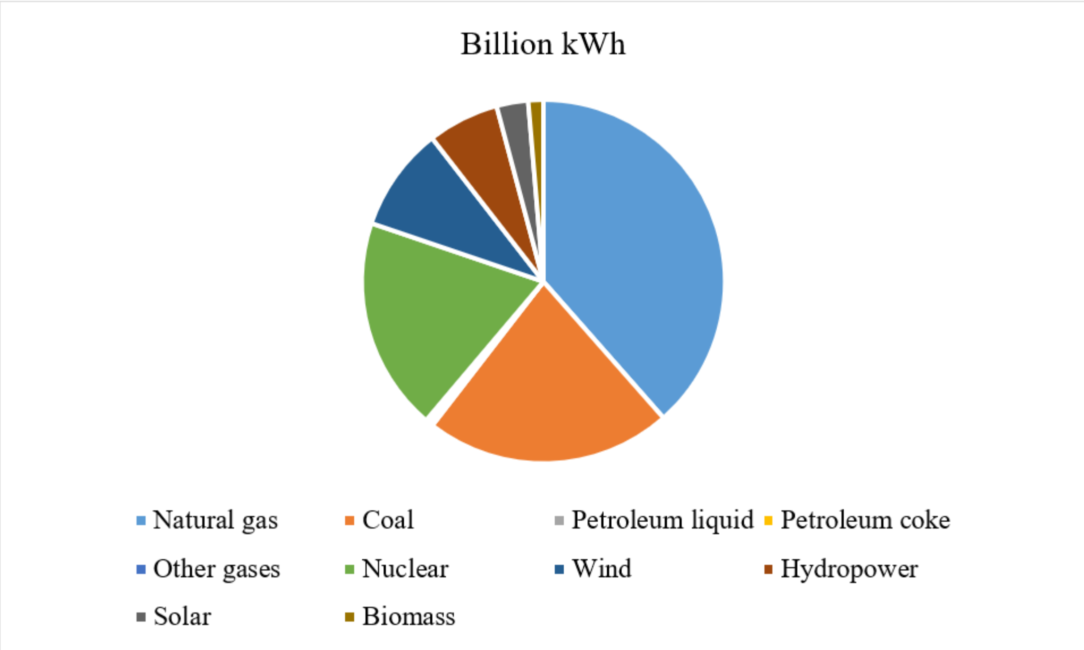

Figure 1: Power data ((as of September 3, 2023, United States (US) Energy Information Administration (EIA) website)).

Among photovoltaic systems, multiple different types of devices are used to convert sunlight to electricity directly such as silicon solar cells and thin film solar cells. Silicon Solar Cells are available to the community with good efficiency at a reasonable price for commercial as well as residential rooftop applications. Thin-Film Solar Cells use thin layers of semiconductor materials such as cadmium telluride or copper indium gallium Di selenide. However, the cost of photovoltaic solar cells is targeted to reduce from 12.8 cents per kWh in 2020 to 5 cents per kWh in 2030 for residential PV and 9 cents per kWh in 2020 to 4 cents in 2030 for commercial PV (as of September 3, 2023, Energy Efficiency & Renewable Energy-EERE office). Therefore, alternative technologies such as perovskite solar cells based on hybrid organic-inorganic materials, Dye-Sensitized Solar Cells (DSSC) and quantum dots are sought and investigated to achieve reasonable cost, efficiency, and stability. Before installing a solar power plant, solar data such as radiant flux (radiant energy per unit of time in Watt, i.e. radiant power), radiant intensity (power per unit solid angle in Watter per steradian) and irradiance (power incident on a unit surface in Watt per square meter) are measured [8]. Different components of radiation are measured differently. For instance, Direct Normal Irradiance (DNI) is measured by pyrheliometers and Diffuse Horizontal Irradiance (DHI), Global Horizontal Irradiance (GHI) or Global Tilted Irradiance (GTI) are measured by pyranometers. The geometric sum of direct and diffuse components is related by the following expressions by solar zenith angle (SZA) [8]:

$$GHI = DNI \times \cos(SZA) + DHI \qquad (1)$$

Similarly, wind energy utilization requires the assessment of field data. Wind resource assessment, for example, wind speed frequency distribution, wind directions, and turbulence are required. A typical wind turbine installation project involves site evaluation, turbine selection, wind resource estimation, turbine orientation i.e. Horizontal Axis Wind Turbine (HAWT), Vertical Axis Wind Turbine (VAWT), tower height, initial cost and Turbine Failure Projectile Zone (TFPZ) [9]. The demand for new professionals in the renewable energy sector has drastically increased with the increased use of renewable energy sources. Governments and different environmental organizations are prioritizing the use of renewable energy sources due to the technological development of renewable sources, increased awareness of energy security, as well as, for the concern for environmental impact of fossil fuels [10]. Different countries in the world are initiating diversified educational and training programs to promote renewable energy education [11]. The role of government has always been investigated in the advancement of renewable energy education. Coordination among the different related departments of government is needed for the successful implementation of policy initiatives on renewables. For example, the Ministry of Education and the Energy Commission of Malaysia have been working together to advance renewable energy education from the primary level of study. They organized programs such as Energy Efficiency Challenges for secondary school students which entail projects and competitions involving Sustainable Renewable Energy and Green Technology [12].

Local government plays a crucial role in increasing the consumption of renewable sources, for instance, solar and wind energy in household activities instead of traditional coal-based sources. The local governments of a few countries, for example, the United Kingdom, Germany, and Denmark have contributed significantly to increasing the consumption of renewables in urban and rural areas [11]. Along with government and national organizations, non-governmental and international organizations are also contributing to the advancement of renewable energy education. The Renewable Energy Institute (REI) aims to develop innovation in the energy sector by offering different training and certification courses, arranging seminars, conferences, and summits with the support of the European government and in partnership with the United Nations Environment Program, and Institute for Intergovernmental Research (IIR) (REI, 2023). Researchers and scholars from different universities, leading experts on renewable energy and members from energy and environmental institutions share knowledge and ideas at these summits. Courses related to renewables were once offered within some engineering courses such as mechanical engineering, electrical engineering, environmental engineering and civil engineering. To advance learning in this sector, many countries have initiated undergraduate, master's, associate and different training programs on renewable energy. From 1952-2012, the carbon emission rate has alarmingly increased in China. The State Council of China formulated the "Energy Development Strategy Action Initiative (2014-2015)" aiming to decrease the coal consumption rate by 62% by 2020 as well as increase the use of renewable sources of energy [5]. In China, policymakers recognize the role of formal education on renewables as well as raising public awareness on how the use of renewables can decrease carbon emissions through the effective use of Information & Communication Technology, as the two useful strategies for reducing carbon emissions and combating climate change [13].

Oregon Institute of Technology is the first university in North America that start a bachelor's program in Renewable Energy Engineering in 2005 and a Master of Science in Renewable Energy Engineering in 2012 [14] to make the students well prepared for energy industries. Some universities in the USA initiated interdisciplinary courses such as Bachelor of Arts in Business Administration with a concentration in Renewable Energy and Bachelor of Science in Energy Management. Many institutions in USS, Germany, UK, Italy, and some other European countries are offering associate degrees/ diploma/certificate courses on renewable energy. A remarkable number of US universities are now offering online courses on renewables. Renowned universities, for instance, Stanford University and Massachusetts Institute of Technology also have online energy courses [15]. The culture of transition from on-campus courses to online versions during COVID-19 has increased the attraction of online courses among students. Online courses may contribute to the skilled manpower on renewables with low costs and easier ways. However, the duration for most online courses is several months/ or one or two years which is sometimes insufficient for effective learning. Also, learning about renewables demands hands-on training and practical experiences. These web-based courses should have practical projects and field work experiments to ensure effective learning on renewables. School-level learning about the basics of renewables is important for increasing students' interest in renewables as their future field of study. Proper policy frameworks with effective strategies are needed to advance the knowledge of renewables among school students which has not been reported much. Therefore, this report shares the experience and endeavors that were made to make K-12 students familiar with renewable energy sources such as solar and wind energy through summer camp activities. Education can meet the growing demand for the renewable energy sector by creating professionals bestowed with specialized knowledge, technical skills in renewable energy supplies, and a commitment to protect the environment. According to Agenda 21 of UNCED, "Education is critical for promoting sustainable development and improving the capacity of the people to address environment and development issues. It is critical for achieving environmental and ethical awareness, values and attitudes, skills and behavior consistent with sustainable development, and for effective public participation in decision-making [16]. Three important factors can contribute to the solving of environmental issues. First, the government's policy-making apparatus should be established based on democratic values. By preserving democratic principles, policy-making organizations are more likely to prioritize public interests instead of short-term narrow interests and work to protect the environment. Secondly, a proper regulatory framework is required that can influence individual and organizational behavior. For example, the government should ban or impose penalties on initiatives or behaviors that are harmful to the environment.

At the same time, offering incentives for using renewable energy sources or for sustainable environmental initiatives. Environmental problems are deeply rooted in social norms and values rather than completely a technical challenge. Thirdly, an effective educational system that promotes environmental education, develops a skilled workforce for technical issues, raises awareness, and influences individual values that safeguard the environment [17]. Education regarding energy issues helps students to be prepared for present and future energy needs. It also enhances the acceptance of the outlook and lifestyle necessary for environmental sustainability [18]. Therefore, educational programs on renewable sources should be included in schools, colleges, universities and other academic institutions [19,20]. There are seven needs recognized for why education and training of renewables should be expanded as identified by [21]. Those are: "retraining of professionals who wish to move into the renewable energy industry; retraining of technicians and tradespeople who wish to work in this field; initial training of scientists and engineers to design and develop new renewable energy systems; training in renewable energy technology and policy for financiers, investors, and policy analysts; short, in-service, professional development courses on aspects of renewable energy technology and policy; lessons and resources for schools on energy issues; and contemporary information about renewable energy technology for the general public". Renewable energy education has been gradually rising as a new discipline of education. Earlier it was considered as a minor subject in engineering. However, only several courses in renewable energy cannot produce knowledgeable professionals and skilled workforce in this demanding sector [22].

At the school level, renewable energy concepts are being introduced to various courses as a part of the science curriculum. Practical learning is an important and effective strategy to attract student's interest in renewable energy from a very early stage. Along with theoretical inquiry, practical activity-oriented learning initiatives should be developed because they include the design and production of works and prioritize active engagement and participation of students. Also, practical learning fosters a sense of curiosity to explore energy issues among the students and develop energy knowledge [23]. Summer camp has become an effective method of teaching for middle school and high school students. It can provide both theoretical learning as well as hands-on experiences for the students. Summer camp provides the children with the opportunity to develop their social and service skills, get hands-on experiences in a particular field, as well as enrich their knowledge and interest in that field of study which is a billion-dollar industry with thousands of individual programs [23]. Summer camp on renewables will cultivate a sense of energy consciousness among the students, advance their knowledge and practical skills on renewable energy, and develop their interest in exploring the field of renewable energy as their future study and career path. Towards this long-term goal, a couple of modules on renewable energy were developed and combined with other modules for the existing summer camp activities at UTPB as a pilot project.

Methodology

The overall objective of the summer camp was to increase awareness and interest in engineering, provide middle school and high school students with hands-on experience in the college environment with many projects, develop strategies and apply methodologies based on their respective learning styles. The 2021 XTO Energy-UTPB Engineering summer camp program was an outreach activity to inspire school students to pursue careers in engineering. This was accomplished through hands-on activities demonstrating principles in mechanical, petroleum, electrical and chemical engineering. However, this paper discusses the modules that were developed and delivered focusing on renewable energy, primarily only on solar and wind energy. Principles and hands-on experience in harvesting solar and wind energy as a renewable source were demonstrated to the students. In addition to increasing interest in engineering overall among high school and middle school students, the objectives of this renewable energy module are:

A. To promote renewable energy and engineering education.

B. To inspire middle and high school students to pursue careers in renewable energy.

C. Teach the students how to generate good quality solar and wind data with low-cost equipment.

D. Increase student's understanding of solar and wind energy and their potential benefits as alternative energy sources to promote a sustainable energy future.

Simplistic approaches are adopted to develop modules for K-12 students and advance renewable energy education from an early stage. This will help them to get an introduction to the process and attract them to the engineering field, more specifically with an energy focus for further developments. During the camp, students from grades 6-8 were offered a four-hour session from morning to noon in week 1 and grades 9-12 another four-hour session in week 2 with a similar topic but with an advanced level in the first year. After the successful execution of the initial modules, further modules on measurement and analysis were developed and delivered in the second year. A module based on an open-source solar tracker was developed in the first year. At first, students were introduced to the working principle of a silicon-type solar cell with p-n junction by photovoltaic effects. Then students assembled a solar tracker using a kit and an Arduino code was loaded into the kit. Students have demonstrated their skills by running those kits successfully. Two different modules are developed for two weeks in the second year. Students collected solar intensity, wind velocity, and temperature at different times for half an hour, plotted, and compared with data published on the website in the first week. In the following week, they built a circuit to characterize a solar cell for voltage-current (V-I) measurements and collected different voltage and current data by varying the load with a potentiometer. This V-I data is used to estimate the efficiency of a solar cell. The following sections describe the modules in detail.

Dual axis tracker

Dual axis tracker is a solar tracking system that receives solar energy and rotates the solar panel to maximize the solar radiation on it from the east and west directions. Along with east-west tracking, the dual-axis tracker inclines the solar collector and monitors the shifting altitude angles of the sun [24]. In the first year of the camp, students learned how to use a dual-axis tracker for monitoring the changing altitude angles of the sun and built one by themselves using a kit. Figure 2(a) shows the different components of a solar tracker. The kit was purchased from Brown Dog Gadgets [25]. With the changing position of a flashlight as tested, the solar tracker rotates the station along the illumination source to maximize the harvest. Two servo motors, i.e., one for horizontal and one for vertical movements are used. The "Servo h" library is used in Arduino programming. Initial servo positions are set to 90 degrees for both servos. Lower and upper limits are set to 65 degrees and 180 degrees for horizontal servo motors and 15 degrees and 120 degrees for vertical servo motors, respectively. There are four sensors on the maneuvering station at four different positions, i.e., top right, top left, bottom right, and bottom left. Analog inputs are read from these sensors and four averages are calculated from these four inputs in the Arduino script. The average value of the top two sensors, i.e., top left and top right is calculated which subtracts the average of the bottom two sensors, i.e., bottom left and right. Similarly, the average of the left sensors subtracts the value of the right sensors. From these two differences, the position of the illumination source is estimated, and the station is kept maneuvering until it finds the optimum position. Once, all of the averages are the same that means it found the optimum position, no further movement is necessary and the servo motor stops rotating. Arduino code is provided in the appendix of this article. Students assembled those components to build it and tested its function with the cell phone flashlight, as shown in Figure 2(b). Four to five students were grouped in teams to conduct the activities. The enthusiasm and activities of highly intensified students while assembling and testing this solar tracker were reported in a local newspaper of Odessa, Odessa American, as depicted in Figure 2(c).

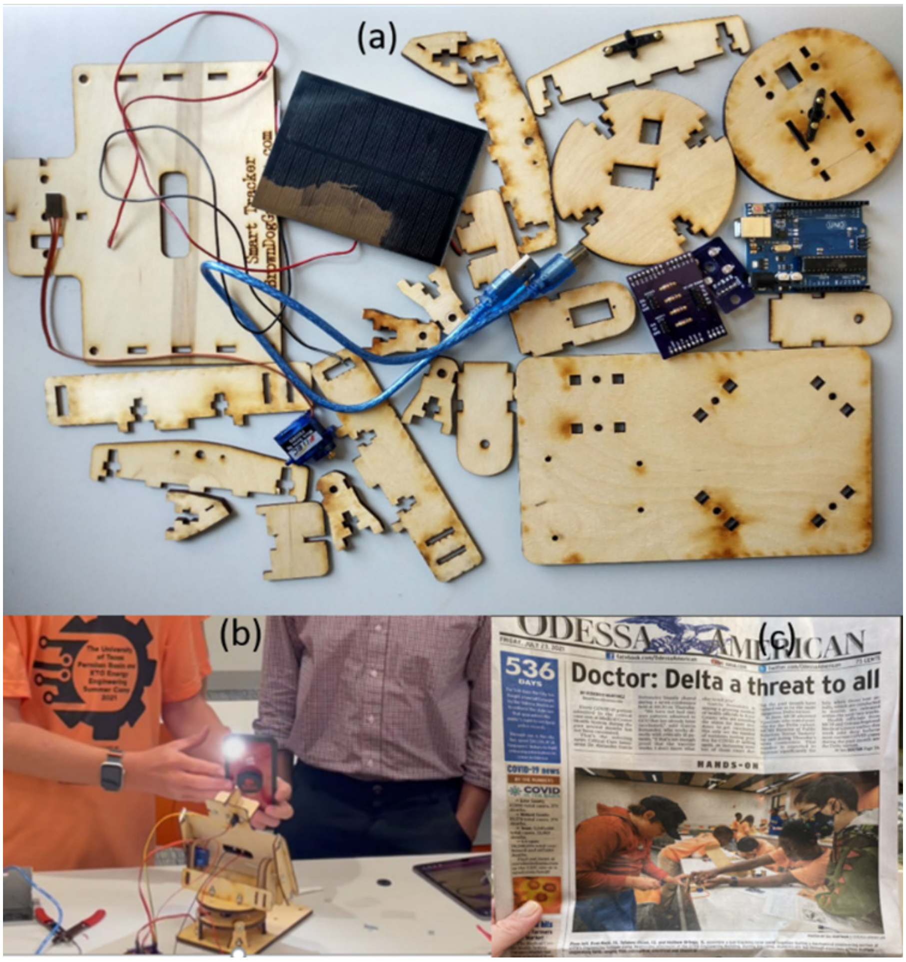

Figure 2: (a) Components of the dual axis tracker; (b) Students testing its performance after the successful assembly; and (c) The Odessa American local newspaper publishing student's activities.

Air velocity and solar intensity

Following the above-mentioned activities in the first year, measurement and characterization modules were developed in the second year. The importance of data harvesting such as solar intensity before installing solar panels or wind velocity at different heights before installing wind turbines was discussed. Then each student group was given one anemometer and one solar power meter. As there were limited pieces of equipment, while a few groups were taking data with an anemometer, a few other groups were taking data with a solar power meter. After that, the equipment was switched to an alternative group. Due to the limited time of the summer camp, each group took data with one equipment for half an hour. Figure 3(a) shows the anemometer and Figure 3(b) shows the solar power meter. These are cost-effective equipment purchased from Amazon. Figure 3(c&d) show students measuring air velocity and solar power, respectively. They also recorded the temperature value. After gathering the data from the field in front of the University of Texas Permian Basin College of Engineering (coordinates of the location 31.97°, -102.25°), students returned to the classroom and plotted their data in Excel. Figure 4(a&c) show average wind velocity, average temperature and average solar intensity at different times, respectively, collected by one group. Then, they were introduced to two different online resources, i.e., Global Wind Atlas and Sol cast toolkit, where they can find these data online for different design purposes [26].

Figure 3: (a) An anemometer; (b) A solar power meter; (c) Students measuring air velocity; and (d) Students measuring solar intensity.

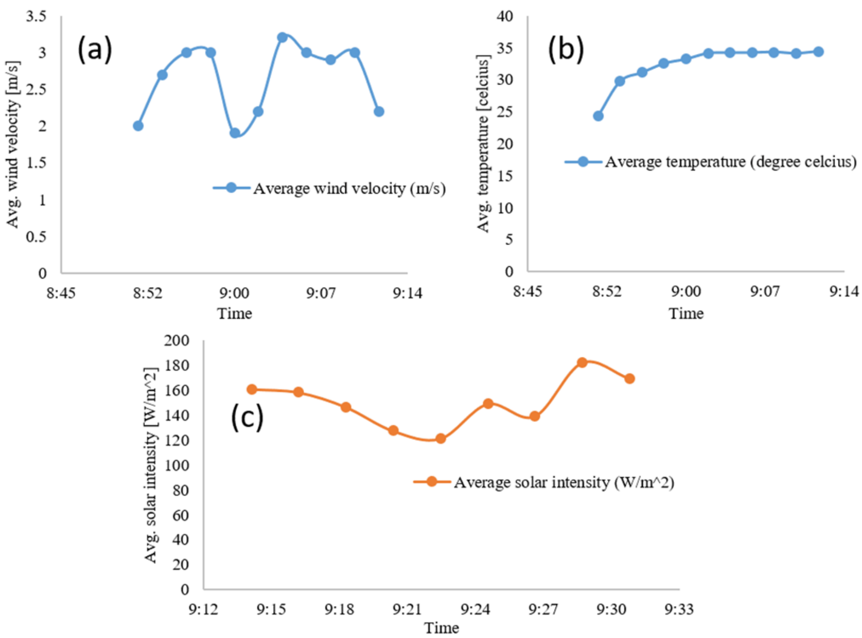

Figure 4: (a) Average wind velocity at different times; (b) Average temperature at different times and (c) average solar intensity at different times collected by the group represented by Alexa Aubrey at geometric coordinates 31.9716859, -102.2490112 on June 24, 2022.

Characterization of a solar cell

The Brown Dog Gadgets Dual cell solar tracker has a 5V silicon type solar cell which has been used to develop another module for the second week this year to characterize a solar cell. Students were given instructions on how to build the required circuit with a potentiometer as a variable load to obtain voltage versus current data at different electrical loads. Figure 5(a) shows the circuit that students built using two multimeters, a potentiometer, a few wirings, and a solar cell with the assistance of undergraduate students during the camp. Figure 5(b&c) show that an undergraduate student volunteer is helping the high schoolers to build the circuit. Afterward, the students went outside to the field, changed the potentiometer load multiple times, collected both voltage and current readings at different loads, and plotted in Excel. Figure 5(d) shows the V-I characteristics curve for the 5V solar cell. This figure can be used to calculate efficiency and other necessary parameters; however, those were skipped for K-12 students as it could be extensive for them.

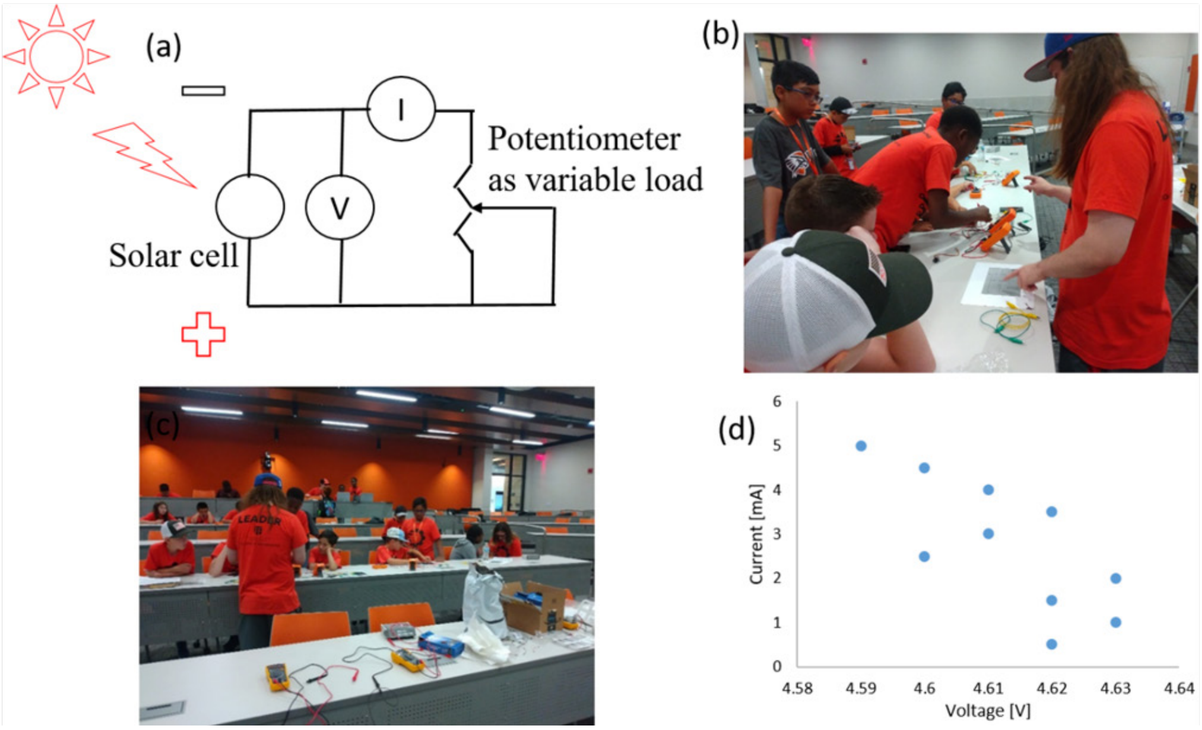

Figure 5: (a) The circuit to characterize a solar cell from dual axis tracker; (b) An undergraduate student assistant helping a K 12 group to build the circuit; (c) Activities of multiple groups while building the circuit; and (d) Voltage-current (V-I) characteristics curve obtained by one K-12 students' group on July 1st, 2022.

Fabrication and demonstration of a dye-sensitized solar cell

On the same day, students were demonstrated how to build a dye-sensitized solar cell. Due to the limited time, each student group did not have a chance to build it and characterize its performance, however, they were demonstrated by building one cell in front of them by the instructor. They were also provided basic information on its working principle. The working principle of a Dye-Sensitized Solar Cell (DSSC) is the same as a semiconductor formed between a photo-sensitized anode and an electrolyte. Electricity can be produced using illuminated organic dyes. DSSC is composed of a thin layer of Titanium Dioxide Nanoparticle (TiO_2) covered with a molecular dye that absorbs sunlight similar to the chlorophyll in green leaves. The transparent electrodes allow the sunlight to pass through it to the dye which absorbs electrons. Then the electron flows to the TiO_2 and later to the electrodes. TiO_2 only absorbs an insignificant number of solar Photons as Ultraviolet (UV) light. It is used to transfer the electron coming from the dye which is the main component to absorb sunlight and emit electrons. The dye is regenerated through the reduction by a redox (Iodide)/electrolyte solution.

The operation principle is given as follows:

Step 1: Rhuthium complex photosensitizers absorb the photon on the TiO_2 surface.

Step 2: The photosensitizer (dye) is excited from the ground state (S) to the excited state (S*). The excited electrons are pumped into the conduction band of the TiO_2 electrode and the photosensitizer oxidizes (S^+).

$$S + sunlight\left(h\vartheta\right) \rightarrow S*$$

$$S* \rightarrow S^{+} + e^{-}\left(TiO^{2}\right)$$

Step 3: The pumped electrons pass through the conduction band of TiO_2 towards the other electrodes and complete the circuit.

Step 4: The oxidized photosensitizer (S^+) is reduced by redox mediator iodide solution (I^-) and comes back to the ground stage (S) and the iodide (I^-) is oxidized to the oxidized state (I_3^-).

$$S^+ + e^- \rightarrow S$$

I_3^- diffuses to the counter electrode and is then reduced to I^- ions.

$$I_3^- + 2_e^- \rightarrow 3I^-$$

A nanocrystalline solar cell kit was purchased from the Institute for Chemical Education (ICE) at the University of Wisconsin [27]. This kit uses a natural chlorophyll die from plants as a light detector. The kit includes tin dioxide-coated conductive transparent glass to be used as electrodes, colloidal titanium dioxide powder as a semiconductor material, graphite pencil, binder clips to attach the electrodes to complete the cell and a 1000-ohm potentiometer. A nitric or acetic acid solution is recommended to create a titanium dioxide suspension batch to paste on the conductive glass. After drying the suspension, homemade raspberry juice was dropped on it as a die [28]. Graphite pencil was used to create a light carbon film on the other conductive glass. Then the two glass electrodes were pressed together with a binder clip and a few drops of iodide electrolyte solution were dropped in between to enhance the charge transportation and chemical reaction to complete a cycle as mentioned earlier. Figure 6 shows the fabricated dye-sensitized solar cell that was demonstrated to the students [29].

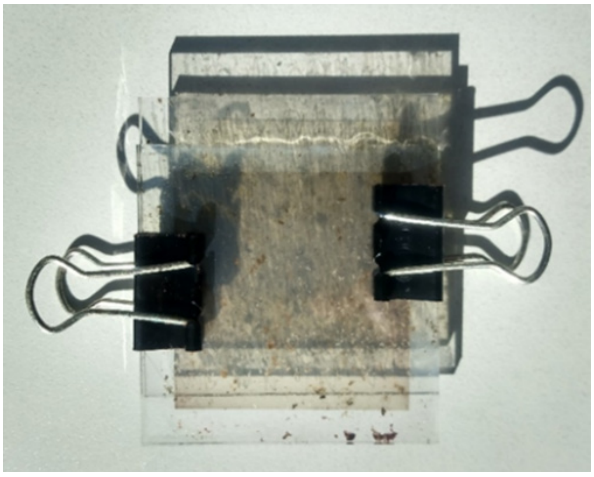

Figure 6: Fabrication and demonstration of a dye-sensitized solar cell.

Analysis and Discussion

At the end of the summer camp program, students were asked to participate in a survey. Data was collected through a survey of the students who participated in the summer camp both in the years 2021 and 2022. For quantitative data, the survey was conducted by following a close-ended questionnaire and for qualitative data, this study followed open-ended survey questions. Figure 7 depicts the demographic location of participants from different cities for the 2021 and 2022 summer camps [30]. We assessed how the camp has influenced students' academic preferences. To know the influence of the camp on students' future academic preferences, students were asked the question, "After participating in this program, "How would you say this program has changed your interest in engineering as a career [2022]"? Responses of the students are presented in Figure 8 for both years which demonstrates that summer camp has highly influenced the academic preferences of the students. The survey was also designed with some open-ended questions [31]. Qualitative data allow us to design future camps by following a student-centered method of teaching. Students' responses to the survey provide insights into the preferences, abilities, and learning styles of students that will help to design better camps in the future. Three questions were asked to the students: What did you enjoy the most about the experience? What can we do to improve the experience? Anything about the camp you want to share with us? Answers of the students reveal the fruitful outcome of the camp by indicating how the camp has increased students' interests in engineering fields specifically in renewable energy as well as developed their understanding of solar and wind energy. It also helps to identify the effective strategies for a successful camp aimed at promoting energy engineering [32].

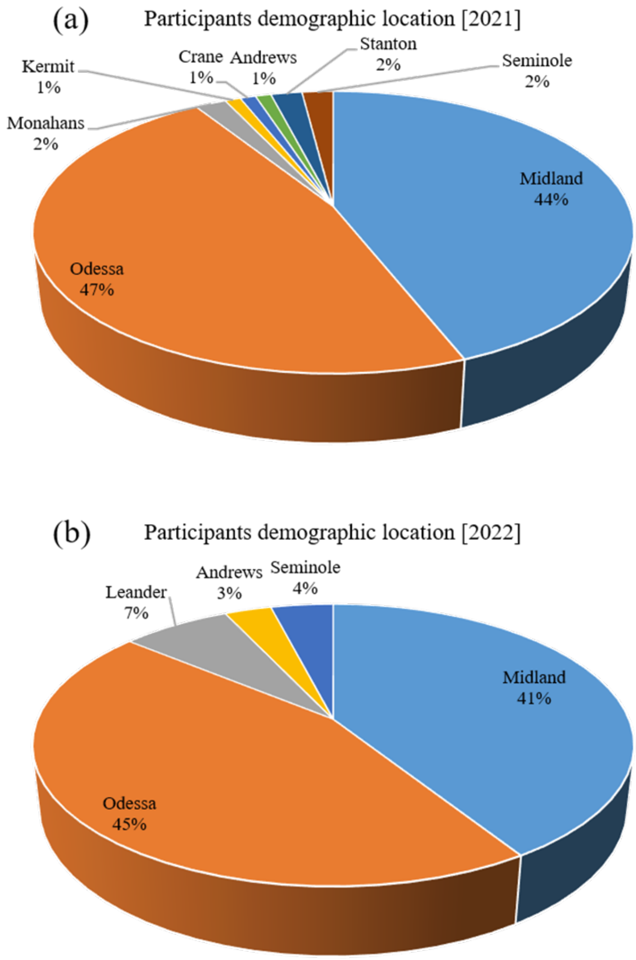

Figure 7: The percentage of students' demographic locations for the year (a) 2021 and (b) 2022.

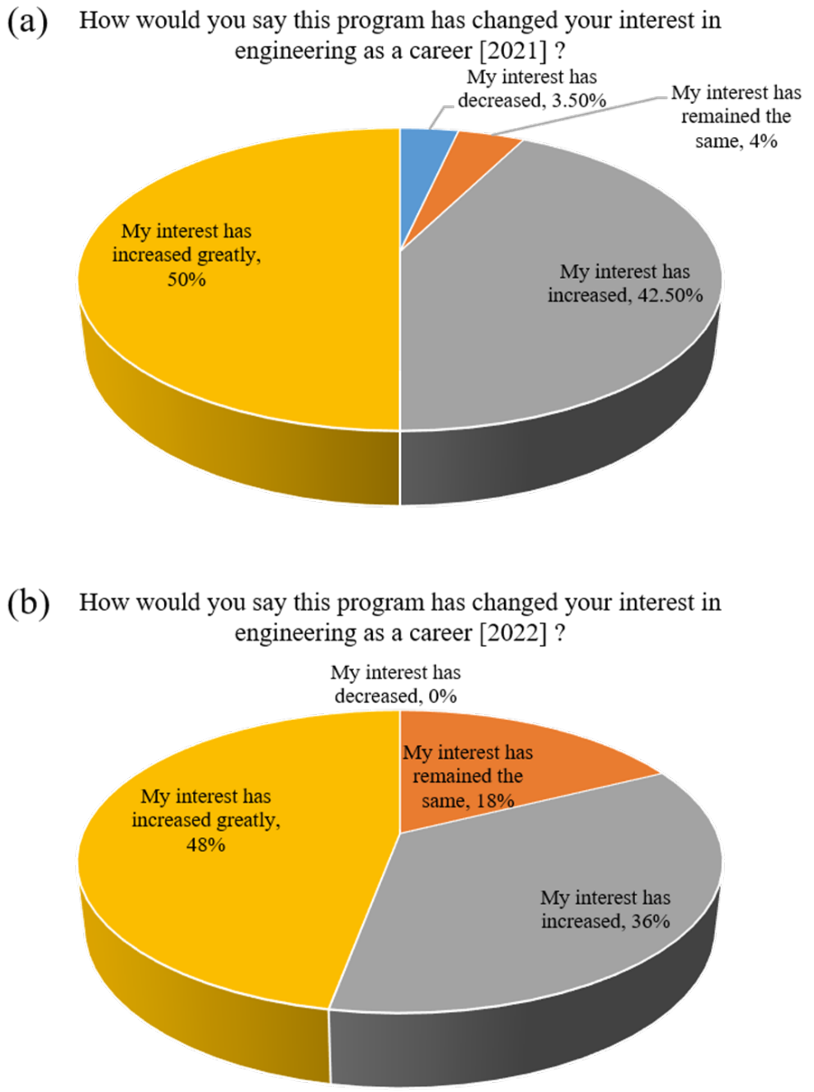

Figure 8: Percentage of student's responses that change their interest in engineering as a career for the year (a) 2021 and (b) 2022.

Students' feedback reflects their high-quality learnings and experiences from the camp. One student said- "I had a great time at the camp even though it only lasted a week. Overall, it is really well organized. Thank you to all the people who took time out of their day to inform us. My fascination with all the subjects taught has grown substantially." Another student stated, "I enjoyed reactions and wind power, solar power. All were fun and interesting." Another student stated, "I had fun and learned stuff that I can apply to several different engineering things [33]. "The above statements from the students indicate that the accomplished projects increased students' understandings and developed their interests in energy and engineering. The success of the camp is echoed in the statements of several students who said the camp was "the best camp they went to". Also, the students conducted some projects through teamwork. Along with the technical skills, the projects allowed the students to improve their skills of leadership, management, and communication. The responses from the students indicate that the camp has successfully aligned with its intended learning objectives. We have also identified the strategies that worked as a basis for the successful outcome of the camp. Most of the projects involved hands-on activities and practical learning. Hands-on activities enable the students to learn and improve their skills beyond the classroom environment. In the question What did you enjoy the most about the experience? most of the student's answers were 'hands-on experiments', 'practical learnings' and 'the labs. "One student stated "The hands-on stuff (build a wind turbine and chemical reactions) was very fun.

Don't remove those from the program." Also, designing the modules interestingly and flexibly is an effective strategy to enhance the interests of school students. Students were engaged in the challenging projects of engineering which are generally conducted in the higher level of study. Those challenging projects were designed in such ways that the students found those challenges interesting. A remarkable number of students stated that they found the projects fun and interesting. Students also enjoyed the flexibility of the modules. One student stated, “I like the schedule that allows for multiple breaks, letting us temporarily excuse ourselves from constant learning.” Some things should be considered in designing an effective future camp [33]. In the question ‘What can we do to improve the experience?’, several students highlighted the need for detailed lessons and step-by-step explanations by the instructor. For example, one student stated, “Longer lessons (mostly Newton’s laws) and more details in subjects” should be considered in designing future camps. Although it is difficult to teach students the details of the lessons because of the short period of the summer camps, lessons should be designed in such ways that would improve students’ knowledge and understanding of the related topics. Students also highlighted the need for more ‘interactive projects and more options for ‘lab tours’ in the future.

Conclusion

This renewable energy module of the summer camp is a way to broaden student’s outlook on energy issues and develop their interests in the field of energy from a young age. These modules of the UTPB summer camp focused on renewable energy sources and their use such as solar and wind energy. The purpose of these modules was to disseminate knowledge to k-12 students on renewable energy sources, technologies, and their advantages to the environment. Also, the camp aims to increase students’ interest in energy fields so that they prefer to study and develop careers in the energy sector. Through this camp, students were engaged in hands-on projects and experiments and were able to learn about the basic working principles and technologies of solar and wind energy. Our survey data indicates the successful outcome of the camp in promoting renewable energy and engineering education. Students’ responses imply that UTPB summer camp has highly influenced the academic preferences of the students. 92.5% and 84% of the students, in the years 2021 and 2022, respectively indicated that the camp has increased their interest in engineering fields. Qualitative data also reveals students’ preferences, abilities, interests and learning styles that would help to design future camps through a student-centered approach to teaching. Along with developing the problem-solving and critical thinking capacity of the students, these modules of the summer camp foster their understanding of renewable energy sources, develop their sense of energy conservation, and inspire them to pursue higher studies and careers in the field of renewable energy. These modules are also beneficial to multiple disciplines such as materials science, electrical engineering, mechanical engineering, computer science, physics, chemistry and chemical engineering, policymaking, and engineering education. For instance, materials processing and fabricating the solar device require expertise in materials science, programming of dual cell tracker requires a computer science background, constructing the device will seek help from mechanical engineering, and making policies regarding energy education and commissioning renewable energy would seek attention from the policy maker. School students may not know exactly what career path they would choose, however, whichever, path they choose, summer camps on renewables would help to develop their knowledge in this field, identify their interests, and decide their desired careers so that can serve the community for a better future.

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APPENDIX:

```
* Dual Axis Tracker
* Brown Dog Gadgets <https://www.browndoggadgets.com/>
// include Servo library
#include <Servo.h>
// horizontal servo
Servo horizontal;
int servoh = 90;
int servohLimitHigh = 180;
int servohLimitLow = 65;
Servo vertical;
int servov = 90;
int servovLimitHigh = 120;
int servovLimitLow = 15;
// LDR pin connections
int ldrTR = 0; // LDR top right
int ldrTL = 1; // LDR top left
int ldrBR = 2; // LDR bottom right
int ldrBL = 3; // LDR bottom left
void setup() {
 Serial.begin(9600);
 // servo connections
 horizontal.attach(5);
 vertical.attach(6);
 // move servos
 horizontal.write(90);
 vertical.write(45);
 delay(3000);
}
void loop() {
 int tr = analogRead(ldrTR); // top right
 int tl = analogRead(ldrTL); // top left
```

```
int br = analogRead(ldrBR); // bottom right
int bl = analogRead(ldrBL); // bottom left
int dtime = 0; // change for debugging only
int tol = 50;
int avt = (tl + tr) / 2; // average value top
int avd = (bl + br) / 2; // average value bottom
int avl = (tl + bl) / 2; // average value left
int avr = (tr + br) / 2; // average value right
int dvert = avt - avd;  // check the difference of up and down
int dhoriz = avl - avr; // check the difference of left and right
// send data to the serial monitor if desired
Serial.print(tl);
Serial.print(" ");
Serial.print(tr);
Serial.print(" ");
Serial.print(bl);
Serial.print(" ");
Serial.print(br);
Serial.print("  ");
Serial.print(avt);
Serial.print(" ");
Serial.print(avd);
Serial.print(" ");
Serial.print(avl);
Serial.print(" ");
Serial.print(avr);
Serial.print("  ");
Serial.print(dtime);
Serial.print("   ");
Serial.print(tol);
Serial.print("  ");
Serial.print(servov);
Serial.print("   ");
Serial.print(servoh);
Serial.println(" ");
// check if the difference is in the tolerance else change vertical angle
if (-1 * tol > dvert || dvert > tol) {
 if (avt > avd) {
  servov = ++servov;
  if (servov > servovLimitHigh) {
   servov = servovLimitHigh;
  }
 }
 else if (avt < avd) {
  servov = --servov;
  if (servov < servovLimitLow) {
   servov = servovLimitLow;
  }
 }
 vertical.write(servov);
}
// check if the difference is in the tolerance else change horizontal angle
if (-1 * tol > dhoriz || dhoriz > tol) {
 if (avl > avr) {
  servoh = --servoh;
  if (servoh < servohLimitLow) {
   servoh = servohLimitLow;
  }
 }
 else if (avl < avr) {
  servoh = ++servoh;
  if (servoh > servohLimitHigh) {
   servoh = servohLimitHigh;
  }
 }
 else if (avl = avr) {
  // nothing
 }
 horizontal.write(servoh);
}
 delay(dtime);
}
```

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