Evolution of Activities in a Smart Grid Summer Camp for High School STEM Students (Evaluation)

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Abstract:

Informal science learning through the university-supported summer porgrams for K-12 students has the opportunity to provide real-world science and technology exposure, and encourage students' interest and efficacy in the science, technology, engineering and mathmetic (STEM) fields. This paper provides the objectives and outcomes of designing a one-week summer camp based on the concpets of smart grid, renewable and power systems for high school students. This camp was designed by university faculty, graduate and undergraduate students, and staff to blend direct instruction with hands-on activities related to renewable energy and the power grid. This paper discusses the design and the effectivemesns of the Smart Grid camp in promoting informal summer STEM education over the period of seven years. Overall, students had positive learning experiences and their confidence in learning engineering and science concepts increased after the program.

1. Introduction

Researchers, government agencies, and educators invested in the future of education strongly suggest that K-12 students be given the opportunity to interact with science and engineering concepts both formally and informally. While the introduction of Next Generation Science Standards (NGSS) has encouraged more integration of engineering in the K-12 classroom, universities engaging with K-12 populations is a value-added proposition, especially in the case of high school students seeking exposure to engineering as a college major and future career [1]. When universities and high schools collaborate on education outreach, students are more likely to be exposed to real-world applications of basic engineering concepts, which gives them more in-depth insight into engineering [2], [3].

This paper shares the best practices in designing a long-term summer program that introduces high school students to electrical engineering, renewable energy related knowledge and relevant hands-on projects to teach power concepts. Because our camp instructors are engineering faculty researching complex problems related to power and energy, we are able to transition research problems into applications for high school students that allow them to learn and master concepts during the Smart Grid camp. The goal of this paper is to share our experience and knowledge in designing an effective precollege education outreach activity by collaborating with graduate students, undergraduate students (including visiting Research Experience Undergraduate (REU) students), and faculty members across several universities. The teaching materials will be freely available to high schools, universities and the general public for adoption.

The Smart Grid camp is a week-long summer program intended for rising high school sophomores, juniors, and seniors. Over seven years, more than 140 students have attended the camp, with an enrollment of approximately 20 high school students each summer. The Smart Grid summer camp falls under the broader education goals of the Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks (CURENT), an Engineering Research Center jointly supported by the National Science Foundation (NSF) and the U.S. Department of Energy (DOE) and led by the University of Tennessee, Knoxville (UTK). CURENT's vision statement is "a nation-wide or continent-wide transmission grid that is fully monitored and dynamically controlled in real-time for high efficiency, high reliability, low cost, better accommodation of renewable energy sources, full utilization of energy storage, and accommodation of responsive load." CURENT also aims for educating "a new generation of electric power and energy systems engineering leaders with global perspectives and diverse backgrounds" [4]. CURENT is a collaboration between UTK, Rensselaer Polytechnic Institute, Northeastern University, and Tuskegee University.

Because NSF ERCs are encouraged to develop an extensive K-12 student outreach strategy, engaging with pre-college students through age-appropriate activities during the school year and in summer happens across all four campuses. This commitment emphasizes the goals of *Educating the Engineer of 2020* [5] and reports from PCAST [1] by encouraging greater collaboration between universities and local K-12 school districts. The Smart Grid summer camp is one of important summer programs that CURENT and RPI host, which also include a

Research Experiences for Undergraduates (REU) exchange program and a Research Experience for Teachers (RET) program. RPI has a long history of holding ERC related summer programs, including the first one held in 2000 and funded by the Center for Power Electronics Systems. Such experience provides best practices to new camp coordinators and allows the sharing of many hands-on activities across multiple summer camps.

The remainder of this paper is organized as follows. First, we will discuss the importance of informal STEM education and describe in detail the precepts of the design of camp activities. Next, we will share some of the activities, including our major hands-on activity: a solar panel project. We will also provide an assessment of the summer camp based on pre- and post-survey data from the students. Finally, we will summarize our findings and lessons learned, and offer future plans going forward.

2. Importance of Informal STEM Education

There are many factors that influence student persistence in pursuing STEM degrees and careers. These factors range from the ways that students are exposed to STEM concepts both formally and informally, learning theories that influence the development of curriculum and programs, and the factors that are more dependent on the student themselves such as efficacy, interest, motivation, or confidence. University collaborations with K-12 schools cannot account for all of these factors, but in the case of summer programs like the Smart Grid camp in this paper, it can foster interest and efficacy through the use of informal learning through real-world applications.

Informal science learning environments are those that foster interest in STEM careers while also encourage students to learn through problems, projects, and other activities that might be similar to those experienced by scientists and engineers [2], [6]. Summer camp sponsored by universities often operate between the worlds of formal and informal science in that they take place in formal learning settings (university classrooms and laboratories) with activities done outside of school time [7]. By allowing students to engage in real-world activities aligned with grade-appropriate standards, camp participant is often able to not only pursue their interests in STEM but also to gain confidence and efficacy in the process.

Self-efficacy is an important concept within education due to the influence that a student's perceptions of their abilities have on other related concepts like motivation, goal orientation, and persistence. When students are successful at and interested in a task, they are more likely to engage in the task in the future due to their prior success; if they fail, they are more likely to avoid the task in the future [8]. Research on undergraduate students' achievement and retention in the major demonstrates that high self-efficacy, especially as it relates to learning engineering concepts, indicates that a student will remain in engineering as opposed to transferring to another major [9].

If pre-college outreach programs like summer camps are meant to continue to build the future engineering workforce by encouraging students to pursue engineering degrees and engineering careers, looking at how informal science experience increases student efficacy can be one way to continue the trend. For the remainder of this paper, we will offer a look into how we have designed a camp to foster familiarity, confidence, efficacy, and interest in electrical engineering concepts related to the power grid.

3. Design of the Smart Grid Camp

3.1. Purpose of Program

The purpose of our Smart Grid summer camp is to provide opportunity for high school students to learn the present and future of energy and power systems through a combination of lectures and hands-on activities. Our program defines a smart grid as a power system that is sensor- and actuator-rich, and is enabled by versatile communication and control systems. An essential requirement of a smart grid is its ability to allow reliable integration of renewable resources with appropriate transmission and distribution infrastructure. A related concept of micro-grid is defined as a small self-supplied power system enabled by distributed energy resources, often involving renewable resources. The purpose of designing a Smart Grid directly relates to CURENT's research focusing on the creation and sustainability of a more resilient power grid focusing on renewables. In recent years, this goal has become increasingly realistic with the decreasing cost of wind turbine and solar photovoltaic (PV) technologies. Thus such renewable energy technologies are relevant and timely topics for future engineers to learn about.

Specifically, students in this program progressed through modules related to power and energy while simultaneously using the knowledge gained each day to build a solar panel system. In additional to individual technologies and components of a power system, the discussion also includes operating a power system as a whole. The system topics include power system economics, and power generation and control. The lectures are interspersed with engineering design processes through the solar panel build, simulations of energy markets, laboratory tours and experiments, and a wind turbine blade design activity.

Each camp cohort has about 20 high school students, age 15-17, most showing interest in engineering and all interested in the STEM field as a career choice. The camp has been advertised on the RPI website as part of the summer activities for K-12 students. The camp attendees are mostly from local high schools, with a few from out of New York State. The camp registration is free, with the instruction and materials support paid for by the NSF ERC program. Out-of-state students who need to stay on campus could do so by paying a room-and-board fee. To apply, a student needs two letters of recommendation. If qualified, a student would be admitted on a first-come first-serve basis. For the past 3 years, the student population has consisted of 70% of male and 30% of female.

3.2. Structure of Activities

One of the aims of the camp is to reflect the research activities in the CURENT ERC. However, it would be impractical to cover the CURENT research activities in great technical details, which are the products of graduate student research. As such, the instructors mostly provide introductory materials to the camp students, with as much hands-on activities as possible. Long lectures are definitely to be avoided.

In addition, each instructor has been asked to observe the following precepts, to keep a student's attention:

1) The activity should be self-contained and able to be completed in one to two hours.

2) The activity should adopt realistic data/examples to reflect real design considerations.

3) Each activity should require active participation from the students. The level of technical difficulty should be age specific. More-complex calculations required in a design activity should be simplified, however, to match the students' mathematics skills and to prevent them from being bog down and frustrated with lengthy calculations.

4) At the end of each activity, students should feel that they have learned about a science-and-technology-supported design process.

5) The activity should be readily adopted by other universities holding similar outreach activities.

The instructors include faculty, graduate students, and undergraduate students. Graduate students would lecture on areas of their research expertise, and undergraduate students would be responsible for the hands-on circuits activities.

3.3. Activity Schedule and Contents

The activities and schedule for the 2018 Smart Grid camp are listed in Table 1. Each weekday is broken into 3-hour morning and afternoon blocks containing a combination of lectures on related topics and 2-3 activities. The schedule is designed such that most of the lectures and discussions are conducted in the morning so that students could spend the afternoons learning about electrical circuits. Throughout the camp, students work on the construction of the solar project in the afternoon of every day. The activities are described in the rest of this section, except for the solar build project, which will be d escribed in the next section.

Table 1. The 2018 CURENT Smart Grid Camp schedule

Time	**Monday (7/9)**	**Tuesday (7/10)**	**Wednesday (7/11)**	**Thursday (7/12)**	**Friday (7/13)**
9:00-12:00	Introductions and CURENT ERC; Introduction to Electric energy systems	Energy conversion; Electricity market**;** Wind turbine power generation	Field Trip to NYISO Control Center	Real-time digital simulation and lab visit; Power electronics and Smart Energy Lab	Wind turbine blade design activity; **Solar Panel session 5**
12:00-13:00	Lunch	Lunch	Lunch	Lunch	Pizza Lunch: Power Grid game (12:00-14:00)

13:00-16:00	Circuits; **Solar Panel session 1**	Wind Farm investment game; **Solar Panel session 2**	Mexican/ Colombian power systems; **Solar Panel session 3**	Magnetization and motor experiments; **Solar Panel session 4**	**Completion/ demonstration of Solar Panel project**

The program topics covered can be grouped into a few main components: Power and Energy Systems; Wind Energy; Power Markets; Power Electronics; and Laboratory Activities.

The ***Power and Energy Systems*** topic is organized into two modules. The first module is an introduction to electric energy systems, which sets the theme of the camp. It discusses examples of energy systems from the electric grid to an electric vehicle. The major components of an electric grid such as transformers, generators, motors, and transmission lines, and their corresponding role in the generation, transmission, and delivery of the energy, are described. Basic principles such as Ampere's Law and Faraday's Law are discussed, to motivate the operation principle of transformers and electric machines. An introduction to renewable energy systems including wind turbines and solar panels is also included to prepare the students for the subsequent activities in wind and solar energy.

Next, students learn about energy conversion, since one of the goals of the camp is to provide students with knowledge about the amount of energy they consume. To that end, students need to know the energy contents of fuels (fossil and renewable) and processes used for energy conversion. The concept of "enthalpy" is introduced as a summation of various energy forms and then used to calculate fuel usage in several activities. For example, students get to calculate the velocity and thrust generated by the hot exhaust gas leaving a jet engine after combustion, and the amount of water in a hydraulic power plant required to keep a 100 W incandescent light bulb on for 1 hour by water dropping 400 ft, assuming perfect efficiency in power generation and transmission (answer: 6638 lb (79.6 gallons)). In the US and Canada, where energy prices for households relatively inexpensive, knowing the fuel implication of energy usage is a stronger motivation for energy conservation.

The ***Wind Energy*** topic consists of 3 modules that focus on wind turbine power generation, a wind farm investment game, and a wind turbine blade design activity. In the *wind turbine* section, students are taught about the history of wind turbines to gain an understanding of the physical size and power outputs of modern units. The percentage of total energy output from fossil, nuclear, and renewable resources by fuel and engine type is presented to help students understand where their power comes from. In the *wind farm investment game* [12], they can use this information to help them compete with each other to site and design a wind turbine farm in the most economically favorable location in New York State (NYS). They must choose a NYS region, land type (mountain top, coastal, farmland), geometric farm footprint, blade size, and transmission interconnection that results in the highest return on their investment. Each decision drives changes in cost and performance variables. Students gain an understanding of capital versus operating and maintenance costs, capacity factor, and the desirable blade length for various wind speeds. By posting the best-yet score for all to see, competition thrives to everyone's benefit.

In the *wind turbine blade design activity*, students work independently or in groups to design the most efficient wind turbine blades (multiple trials are allowed). Using a sturdy material such as cardboard, students will choose the dimensions (length, width, and shape) and number of wind turbine blades to be fixed to a miniature functional wind turbine generator. The output of the wind turbine generator is connected to a DC voltaic multimeter to measure the power generated by the blades. The students compete to iteratively design the wind turbine blade configuration that produces the highest voltage when exposed to the winds created by an electric fan. This is a fun and exciting module where students can immediately see the results of their design thinking. Many students are surprised to find that a 3-blade arrangement is much more efficient than a design with 4 or more blades.

The ***Power Market*** topic consists of three activities. The first module is on *wholesale electricity markets*. The challenges facing New York State's transmission system are presented and students learn why electricity markets are needed. Daily power consumption curves for the summer and winter show how intraday shifts in demand and pricing are seasonally dependent. Using a simple scenario, students calculate energy prices with and without transmission congestion with the goal of understanding the complexity of the entire system. For the second activities, students visit the recently constructed *New York Independent System Operator (NYISO) control room* facilities. In our experience, this part of the camp puts theory into practice. The students ask informed questions based on their earlier training in energy markets and are generally eager to see if the places they selected in the Wind Farm Investment Game actually have wind farms.

The third activity is for students to play the *Power Grid board game* [13] over lunch. The objective of the game is to build a network to a predetermined size. The player whose completed network supplies the most cities with power wins. Players can mark pre-existing paths between the cities for possible connection, and then bid against each other to determine who will purchase the power plants needed to power the cities. As an additional difficulty, players must acquire the raw materials (e.g. coal, oil, uranium) that are needed to fuel the plants, but renewable plants (solar, wind) require no fuel and thus no materials. Players thus vie to upgrade their plants to reduce cost while still maximizing efficiency of dispatch and securing the cheapest routes.

To broaden the students perspective on power grids, if an international visiting scholar to CURENT is available, a discussion of a non-US power system will be included in the schedule. In the 2018 summer camp, Profs. Mario Arrietta, UNAM, and Alejandro Zamora, U. Michoacana (both universities are in Mexico) described the Mexican and Colombian power systems to the students, pointing out the importance of electric power supplies in these countries and their differences compared to the US system. In previous years, the Brazilian power system was discussed.

The ***Power Electronics*** topic consists of both a lecture part and a Smart Energy Laboratory visit. The first part of this lecture is an overview of power electronics. The students are introduced to the basics of energy conversion using power electronics and shown real examples of its application in their everyday life and at large scales. The concept of ac-dc conversion is introduced to the students, along with the basic circuitries associated with practical converters. Most concepts are tied to examples they might be familiar with, for example, the ac-dc converters in the chargers for smartphones, and dc-dc converters inside their computer's power supplies. The applications of power electronics in wireless chargers and electric vehicles are also presented as a means to introduce the students to new developments. Finally, the use of power electronics in the generation and transmission of electrical power is presented, with a focus on wind and solar based generation.

The second part of this program is a Smart Energy laboratory visit. Due to safety considerations, the number of students touring the laboratory has to be limited to no more than 3-4 at a time. For the students remaining in the classroom, they are shown two different commercial PV micro inverters of different topology and power level, as well as three different converters that have been built by undergraduate and graduate students in different power electronics courses offered at RPI. The goal of this exercise was to connect the circuitry and designs introduced in the lecture with physical components and to better utilize students' time.

The ***Laboratory Activities*** consist of two parts. The first part includes *Magnetization and Motor Experiments* such as the coin flipper which energizes a flat spiral coil. The resulting eddy current effect launches a coin more than thirty feet into the air. Various combinations and types of coins are studied, allowing further discussion on the effects of conductivity and eddy currents. The Beakman's Motor project is prefaced with the segment from the humorous television episode [14], where the basic principles of how an electromagnet interacts with a permanent magnet are explained. Following the video, students build their own motor, with nearly all students completing the project successfully. A particularly noteworthy observation is how students both offer and ask for help from their peers. The students also visit the undergraduate Electric Power Laboratory to see an induction motor experiment.

The second part is on *real-time digital simulation (RTDS) and visualization* of power system dynamics. First, students attend a lecture introducing basic concepts about real-time simulation, modeling, and synchrophasor technologies. Then three demonstrations are shown to the students. First, synchrophasor measurements are displayed on a monitoring system, as shown in Figure 1. Second, the simulation of a small power system is shown to the students. Afterwards, the students can interact with a microgrid simulation on the RTDS computer. The students are encouraged to "play" with the demo, to make changes to wind speeds, solar irradiance, and load consumption.

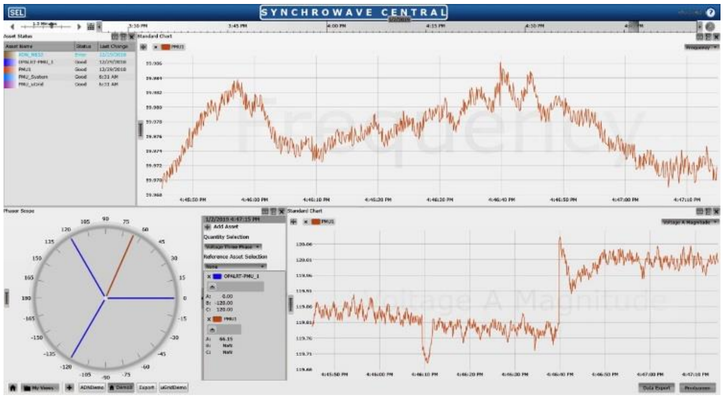

Figure 1: Display of frequency and voltage measurements from a prototype phasor measurement unit

3. Solar Panel Project

A major part of the summer camp activities is for the students to construct the "solar build" project. A prototype was developed 4 years ago by several undergraduate students, most of them from Tuskegee University, spending their summers at RPI supported by the NSF Research Experience for Undergraduates (REU) Program. After 2 years, the project has significantly refined and the summer camp faculty decide to include the project as part of the summer camp.

To summarize, the solar build is an electronic circuit consisting of an Arduino microcontroller, current sensor, solar cell panel, and Bluetooth™ module. The goal is to measure the power generated from the solar cell panel (4.5 in by 4 in, 6 volts, 2 watts), and send the data via Bluetooth™ to either a laptop or smartphone for visualization. The project consists of the construction of the device, learning fundamental concepts (e.g., Computer Science (coding), Circuits, Energy, and Physics), and hands-on activities for each concept.

The project is broken into 6 modules where each module includes a different step of the construction of the device. Students begin by creating a circuit on a breadboard using an Arduino, current sensor, 9V battery and LED in order to test the power reading. Afterwards, the circuit is placed within a container and the 9V battery is replaced with a solar cell panel. The 9V battery is then used for providing power to the Arduino through a 9V battery connector. Finally, the Bluetooth™ module is connected to the Arduino and the task code is stored into the Arduino's memory. The final device is shown in Figure 2. An app has also been developed for a smart phone to monitor the power output of the solar panel (Figure 3). Videos on these 6 modules have been posted on http://engineeringambassadors.union.rpi.edu/reach_home.php.

Throughout each module, students learn concepts that relate to how each part of the device works. This includes coding, circuitry, energy, physics, data transmission, and solar cells. The program is optimized for students to grasp the fundamentals of these topics and to understand and explain to their friends and family how the device works. The modules are also based on the Next Generation Science Standards (NGSS) for high school. The cost for each project is about $120. After completing the project, the students are allowed to bring the "solar build" project back home to show their family.

Hands-On Activities: Students also conduct additional short activities that help relate each concept learned toward the individual parts of the overall construction of the device. One of the activities is to find the max power point of the student's solar cell panel by using different load resistances and a multimeter. The students find the power generated by the solar cell panel for each load; then, draw a graph of power vs voltage. Another activity is deciphering a Bluetooth™ signal into binary and then into ASCII characters.

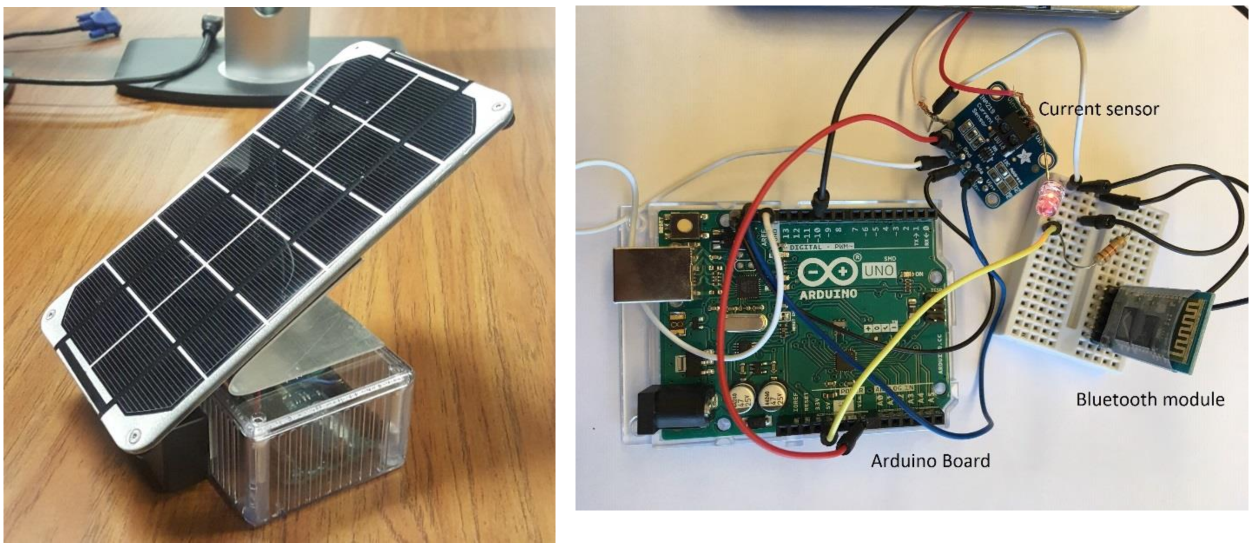

Figure 2: (Left) Solar Build Project, and (Right) circuit components inside box

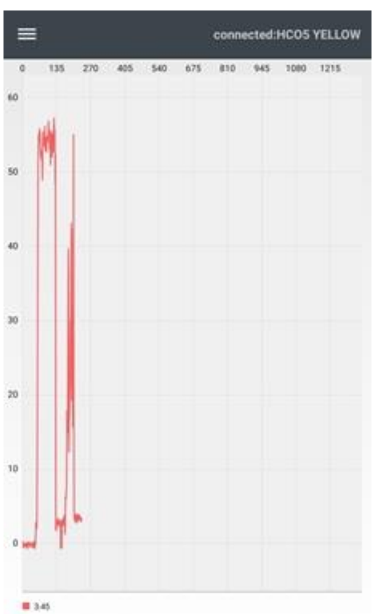

Figure 3: Phone app to monitor the solar panel power output

4. Assessment

4.1. Data collection

CURENT's education team, which consists of one faculty member from the department of sociology and an education coordinator specializing in engineering education, have conducted assessments of the campers. Program assessments have consisted of the pre- and post-surveys, which are designed primarily to measure the campers' interest and confidence before and after the camp. The post-survey also measures overall program satisfaction and evaluation on specific hands-on projects and so on. All the survey questions used a 5-point Likert scale with 1 being strongly disagree/not at all and 5 being strongly agree/extremely.

The main measure used to assess the effectiveness of our program is the difference in STEM interest and knowledge between the pre- and post-surveys. Our program did not conduct any longitudinal tracking of students' performance until they entered college partially due to privacy concerns under FERPA guidelines and the difficulty in relying on the students to voluntarily report their performance back to us. More important, we take precaution not to over-attribute the students success or interest to our program. Factors such as social economic background, family support, and school learning environment are all shown to have substantial impacts on students' academic performance over time. In addition, STEM education or exposure must be applied on a continuous basis for these high school students in order to be effective. Our Smart Grid program is after all only one of the many opportunities to shape these STEM students. The use of the pre- and post-survey method allows us to assess the immediate effectiveness of our instructional materials, without being impacted by other factors. As such, it is applicable to a wider spectrum of students, as a few past students were not STEM inclined.

Specifically, the confidence in STEM learning is measured by having the participants rate how confident they are in doing hands-on projects, discussing STEM ideas, studying STEM in college, and becoming a future engineering or scientist (Cronbach's $\alpha_{pre} = 0.87$ and Cronbach's $\alpha_{post} = 0.91$). The variable of interest is measured with two sets of questions including one measuring the general interest in engineering, where the campers rate interests in engineering on the dimensions: unappealing-appealing, unimportant-important, unexciting-exciting, and boring-interesting" (Cronbach's $\alpha_{pre} = 0.83$ and Cronbach's $\alpha_{post} = 0.91$). The other is on the interest in specific STEM concepts, where the campers rate their interests in learning engineering concepts, math concepts, and science concepts (Cronbach's $\alpha_{pre} = 0.71$ and Cronbach's $\alpha_{post} = 0.97$). Because the sub-questions under each variable demonstrate good internal consistency based on Cronbach alpha levels, their average scores are used to represent each variable (e.g., interest and confidence).

4.2. Results

The pre- and post-assessment analyses are conducted with IBM SPSS 25 with all the data that are available and can be matched from 2012 to 2017. Paired-sample *t* tests are conducted to compare the participants' levels of confidence and interest before and after the program. It is important to note that some participants do not complete both the pre- and post-surveys in certain years, making it difficult to match the data; therefore, our analysis discarded those responses.

The following analysis reports the available data and the two variables for Year 2012-2014 and 2017.

4.2.1. Results of confidences and interests of learning engineering and STEM concepts

Examining our students' interests and confidence levels before the program, we have found almost all students ($N_{total} = 55$) report themselves having a strong interest in learning engineering and are confident about STEM learning: the averages are higher than 4 on the 5-point scales. The interest in learning STEM concepts is relatively low before attending the program - the average is approximately 3. After the program, however, we have found an encouraging increase from 3.08 to 3.61 on this variable, and the improvement is statistically significant. Table 2 lists the details of the comparisons between pre- and post-surveys. Participants' interest in engineering remains high after the program: there are no statistically significant differences between pre- and post-surveys on the overall score or each individual item. This result indicates our participants have a stronger interest in learning engineering than overall STEM concepts. We have also found that the participants' confidence in STEM learning stays at about the same high level after the program. Further analyses on the sub-questions show that participants' confidence in doing hands-on projects is indeed improved among all the aspects from an average of 4.06 (SD=0.90) to an average of 4.39 (SD=0.79), $t = 2.46$, $p < 0.05$.

Table 2. Pre- and Post- mean scores of major variables

Year	Pre-Survey		Post Survey		*T*
	Mean	*SD*	*Mean*	*SD*	
Confidence STEM learning	4.03	0.68	4.08	0.73	0.43
Interest Engineering	4.34	0.52	4.26	0.77	-0.72***
Interest STEM concepts	3.08	1.17	3.61	0.93	3.70

*** $p < 0.001$. The slight decrease of 0.08 point from the pre-survey to the post-survey in interest in learning engineering is not statistically significant.

4.2.2. Overall satisfaction and evaluation

Over the years of 2012-2014 and 2017, participants rate themselves as satisfied with the program based on the 5- point scale ($M = 3.87$, $SD = 0.74$) and there are no differences across the years. When each program activity is individually evaluated in Years 2013, 2014 and 2017, all program activities receive positive evaluations. Overall, participants enjoy the activity of Wind Turbine Design the most, followed by the Introduction to Electricity Market. However, the ratings vary across the years. Table 3 reports the overall evaluation on the program activities.

Table 3. Overall evaluation (average) on the program activities

	Intro to Power System	Turbine Design	Intro to Power Electronics	Intro to Electricity Market	RPI Energy Management System
Overall	3.84 (0.68)*	4.27 (0.72)	3.42 (0.90)	4.19 (0.69)	3.52 (0.71)
2013	4.22 (0.67)	4.22 (0.67)	3.44 (0.73)	4.38 (0.52)	3.89 (0.78)
2014	3.69 (0.60)	4.29 (0.77)	3.29 (0.92)	4.18 (0.64)	3.29 (0.69)
2017	3.71 (0.76)	4.29 (0.76)	3.71 (1.11)	4.00 (1.00)	3.57 (0.54)

* Standard deviations are in the parentheses

5. Conclusions and Future Plans

This paper describes the Smart Grid summer camp held at Rensselaer Polytechnic Institute annually for the last 7 years. In the earlier years, the camp has mostly consisted of lecture-type instruction. However, with the introduction of the solar build project, the lectures have been shortened. In this new program layout, the breakdown between lectures, activities, and solar build is about 33%, 30%, and 37%. By doing this, we have achieved our goal of mimicking the college setting for studying engineering, raising awareness of the future of power systems, and obtaining some basic circuits and coding skills. The solar build is a tangible result of their one-week worth of work.

We believe that the increases in student confidence and interest, as demonstrated by the pre-and post-survey results, are important for developing self efficacy in high school students so that they will pursue engineering degrees and careers. Research shows that when students' previous success lead to their believe in achieving a task and students will continue to engage in that task with the expectation to be successful [8]. Additionally, believing in their abilities means that students may move beyond working for a grade and work to master the content [10]. Research has shown that there is a direct correlation between undergraduate engineering students' persistence in their major and, thus, retention [11]. By fostering interest and confidence as early as in high school, we hope to retain students within engineering disciplines. The Smart Grid camp can be one tool to help with that. Obviously, our program has some self-selected participants who may have already established some interest in STEM leaning. Despite this fact, it is encouraging to find the fact that we observed an increase in STEM interest and confidence even among those students. It is important to point out that among the recruited students, some students stated interest in bio-engineering but not power engineering in pre-surveys, and those students experienced the same level of growth as other students. This demonstrates that pre-exisitng interest is not a prerequsite of the success of our program.

The activities done during this summer camp are readily scalable for other pre-college engineering outreach programs. Because the Smart Grid summer camp can only accommodate 20-24 students each year, it is important that its activities can also be used to support other RPI K-12 education outreach activities in the School of Engineering and by other universities for similar purposes. The wind farm investment game has been used by the RPI undergraduate Engineering Ambassadors for on-site outreach at local high schools—as it can be completed within a single class period. We are continuing to find ways to make the program available to more high schools that are underserved in science and technology subjects. With CURENT's support, it may be possible to provide the solar built materials to add the outreach program to underserved programs or clubs. Materials for this Smart Grid Camp will be made available on the CURENT ERC website. Interested institutions are free to use any or all of the posted materials.

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