# A Week-Long Immersive Summer Program in Energy Science and Engineering for Teacher-Student Co-Learners

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## Abstract

STEM education has expanded from classroom settings to informal or afterschool programs to incorporate more resources that can further facilitate and enhance the learning process. A growing number of informal learning programs include a variety of STEM subjects, including energy science. This study describes and evaluates a week-long immersive summer program in energy science and engineering that highlights the learning process and interactions between teachers and students as co-learners. The program incorporates lectures, field trips, hands-on activities, research projects, and the development of lesson plans. We used surveys and open-ended questionnaires to measure participant reactions and gain participant feedback on the program activities. Participants indicated a preference for the hands-on activities and field trips. Teachers expressed appreciation for the knowledge gained in energy science, while students particularly valued their social interactions with teachers during the program. Future programs could be improved through changes to lecture length, frequency, and delivery. Challenges include maintaining resources and stewardship.

## 1. Introduction

A. Background Study

The National Research Council emphasizes the importance of informal learning programs to science education on a national scale [1]. Informal learning programs shift the focus from teaching methodology as a center of the learning process to understanding how youth learning occurs. These programs allow learning ecosystems to evolve by considering multiple influences on individual learning, such as institutions, teachers, industries, media, and technology [2]. For these reasons, STEM learning and education has expanded from teaching through institutions to afterschool learning programs.

The number of afterschool STEM learning programs has increased over the years. The National Afterschool Alliances Survey in 2011 suggested that 85% of majority program providers emphasized math, 63% emphasized geology/earth science, 53% emphasized engineering, 51% emphasized biology, and the remaining providers emphasized other topics such as robotics, computer science, etc. [3]. Several studies also documented afterschool learning programs in teaching energy sciences utilizing various teaching methodologies such as workshops [4], courses [5], hands-on activities [6], and problem-based learning [7] for teachers as well as for students [8], [9], [10]. Most of these energy science education studies tend to consist of either teachers or students as participants and provide little interaction between these two types of participants as co-learners in the same program.

Research suggests that effective afterschool programs need to be engaging (intellectually), responsive (to interest), and make connections (STEM learning out of an academic environment) [11]. Furthermore, effective afterschool programs also include the following characteristics: provide first-hand experiences with phenomena and materials, establish a supportive learning community, leverage community resources and partnerships, support young people to collaborate and to take on leadership roles in STEM learning activities, and position staff as co-investigators and learners alongside young people. Further, a report by consultant Robert Half suggested that individuals from the current generation of students need frequent feedback on their activities [12].This finding emphasizes the importance of mentorship in helping younger generations of students to develop technical, social, and working skills as they prepare to enter the workforce. In the present paper we describe the development and assessment of an energy science afterschool program that considers the interaction between teachers and students as co-learners within the same program.

B. Duke Energy Academy at Purdue (DEAP)

1. Objectives

This paper describes a week-long immersive summer program in energy science, the Duke Energy Academy at Purdue (DEAP), which was designed for both high school teachers and students to participate as co-learners. Overall DEAP goals are (1) to inspire future leaders in energy science, (2) to provide pedagogical resources and inspire teachers to communicate the importance of STEM and energy scholarship to their students, and (3) to inspire students to enter STEM disciplines and consider energy-related fields in their future professional and career goals.

2. Participants

a. Recruitment Process

The DEAP program had four considerations in selecting teacher and student participants: (1) merit, (2) geographic region, (3) ethnic spread, and (3) gender balance. The DEAP has been held for seven years and made selections from a number of high qualified applicants every summer. In partnership with the Duke Energy Foundation Indiana, DEAP aimed to recruit 80% of qualified applicants from Indiana and Duke-served territories outside of Indiana. The other 20% of applicants were selected from areas that are not served by Duke Indiana. About 20% of qualified participants included underrepresented ethnic groups; the process of balancing gender was contingent upon existing gender composition after the merit selection stage. DEAP participant recruitment was marketed through the Purdue website, educational conferences, social media, and partnering community organizations, educational institutions, and related industries.

b. Selection Criteria

In general, qualified students had at least a 3.7 grade point average and were evaluated based on their essays in response to the question, “Why would you like to be part of the energy academy and what are your expectations from the academy?” The essays were graded on student expression and demonstration of their personal passion, interest, aspirations and goals for learning energy science, and how well these descriptions reflect the goals, mission, and vision of the energy academy.

Teacher participants were selected based on the evaluation of essays responding to each of the following two questions: (1) “Why would you like to be a part of the energy academy and what are your expectations from the academy?” and (2) “How do you plan to incorporate information from the energy academy into your academic activities?” Teachers were required to discuss and elaborate on their expectations, personal interests, and aspirations, as well as their proposed goals and ideas of how they would implement their energy science learning materials into their academic activities after participating in the program. These essays were evaluated on how well their answers captured the goals, mission, and vision of the energy academy. Both the teacher and student essays were evaluated blindly by an ad-hoc selection committee that consisted of teachers, Purdue faculty, and representatives from industry. Scores were combined to produce a merit list.

c. Demographic Data of Selected Participants

A total of 110 secondary science teachers (63 females and 47 males) and 176 high school students ranging in age from 15 to 19 (104 boys and 72 girls) participated in the DEAP program in the span of seven years. More than 80% of accepted participants originated from the state of Indiana. Most teacher participants identified as Caucasian (92), followed by Asian/Asian American (6), Latino (5), and Pacific Islander (1). Six participants identified as some other race/ethnicity. Student participants reported being a rising senior or junior in high school and the majority identified as Caucasian (83.5%), followed by Asian/Asian American (10.8%), Latino (2.3%), Black/African American (1.7%), and other (1.7%).

## 2. Program Description

DEAP was a week-long summer immersive energy science program that allowed teachers and students to be co-learners while engaging in multiple activities together. Teachers and students stayed in a Purdue University residence hall during the program week. DEAP was financed by co-sponsors, and all individuals participated in the program free of charge. In addition, teacher participants also received a stipend and continuing education units to maintain their teaching certification.

A. DEAP Activities and Schedules

The DEAP program provided engaging resources and experiences that not only impact participants’ future professional careers but also the energy science field. The DEAP incorporated institutional and industrial leadership as well as new and emerging technologies to develop and implement unique activities that engaged teachers and students in the learning process and stimulated interest in energy science and engineering fields. These learning experiences covered STEM energy-related topics such as energy efficiency, power transmission, power generation, energy utilization, and new frontiers in research. The DEAP program included the following components:

a. *Lectures*: Lectures were delivered by guest speakers (e.g., government officials, energy-related industry leaders, and Purdue University professors) on future energy challenges, renewable options for energy production, advanced technology in energy engineering, and energy-related career opportunities.

b. *Field Trips:* Teachers and students took tours of solar and wind farms, a nuclear reactor, a waste digester, a fossil fuel plant, and a propulsion laboratory where the participants were exposed to various mechanisms, technologies, and processes of energy production, engineering, and management in the real world. These tours were also intended to introduce participants to various types of energy-related jobs and careers.

c. *Research Projects:* Students and teachers were divided into several groups and assigned to one of several energy-related projects developed by researchers at Purdue and industry partners. Participants were provided with an opportunity to learn about current topics in energy science, engineering, and policy by working side-by-side with leading researchers in the field and with a group of peers. Each group set certain times every day to conduct background research and analyze data in order to produce and deliver a technical presentation and policy-related discussion on their project topic during the academy's closing ceremony. The following are examples of their energy science-related projects:

   a. The Science of Photovoltaic Solar Cells: Fabrication and Characterization of Dye-Sensitized Solar Cells from Berries
   b. Rechargeable Batteries with Advanced Electrode Materials
   c. Fuel Cells: Catalysts for Energy Innovation
   d. Understanding Nuclear Fuel and Radiation Decay Chains
   e. Plant Biomass for Biofuels

d. *Hands-on Activities*: Participants were divided into groups, each of which included at least one teacher who served as a guide; they participated in practical exercises to understand energy concepts and how to work with cutting-edge technologies and engineering designs to solve energy challenges. Hands-on activities included

   a. Snap Circuits: Transmission and Distribution
   In this hands-on activity, both students and teachers worked together on a Snap Circuit kit to physically demonstrate the concepts of power transmission and distribution, providing fundamental information on circuitry and the electrical grid. This exercise served as a visual of how electricity is transmitted from power plants to cities and then distributed to various households.
   b. Wind Turbine Challenge
   Students and teachers worked together to come up with various wind blade designs. Participants then used their wind blade designs to create wind turbines that could be tested in a wind tunnel. This activity stimulated students' interest in generating and testing new energy engineering ideas that utilize wind as a source of renewable energy.
   c. Drone Challenge

During this activity, students learned about the importance of drones in monitoring energy infrastructure and how drones play a role in improving safety throughout industrial plants. This activity begins with lectures introducing participants to drones and drone policy, the use of drones and the development of drone sensors in energy and manufacturing industries, and instructions on flying drones. After a demonstration by drone experts, students and teachers were given the opportunity to fly their own drones.

d. Raspberry Pi Challenge
This activity involved using a Raspberry Pi kit to teach participants the concept the *Internet of Things*. These small-board computers can be used to control lights, move motors, and open/close small gates. Student participants were allowed to take their kits home so that they could carry out advanced level activities using open source web resources.

e. Energy Education Exercises: Solar Angle, Windfarm Challenge, Principle of Grid Operation, and Lego Mindstorm
This session was a set of four activities, each offering a different set of challenges. The challenges scaffold from previous activities or introduced totally new concepts to the participants. These activities allowed participants to apply concepts of wind generated power to develop a wind farm to achieve the highest efficiency possible, learn basic concepts of flowchart programming using LEGO Mindstorm robotics, and understand the effect of a solar PV array's angle on electricity production.

f. Energy Lesson Plans: Teachers were asked to develop a lesson plan that incorporated energy materials into their classroom curricula. All teachers were provided with a template and example of the lesson plan during the teacher session on the first day of the program. The lesson plans included the following six elements: (1) incorporating Next Generation Science Standards or Common Core State Standards, (2) asking questions and defining problems, (3) analyzing and interpreting data, (4) use of technology and software, (5) collaboration, communication, and assessment plans, and (6) critical thinking. Teachers were given an opportunity to interact and share drafts with mentor teachers while developing their lesson plans during the program. Finally, teachers were asked to share their lesson plans at the end of the program. These lessons were posted on the website for dissemination.

Table 1. DEAP schedule

| **Day** | **DEAP Program Activities** | |
|---|---|---|
| Sunday | Teacher | Student |
| PM | Registration and Introduction | |
| | Pre-Assessments | |
| | Introduction to lesson plan | Briefing on research project |
| | Inaugural Ceremony, Guest Lectures, and Dinner | |
| | Daily Assessments | |
| Monday | Teacher | Student |
| AM | Guest Lectures | |
| PM | Guest Lectures | |
| | Hands-On Activity | |
| | Guest Lectures | |

| | | |
|---|---|---|
| | Work on the lesson plan | Background on research project |
| | Daily Assessments | |
| Tuesday | Teacher | Student |
| AM | Hands-On Activity | |
| PM | Guest Lectures | |
| | Hands-On Activity | |
| | Campus Tour | |
| | Daily Assessments | |
| Wednesday | Teacher | Student |
| AM | Research Projects | |
| PM | Hands-On Activities | |
| | Working on topic finalization for energy science lesson plan | Collecting research data |
| | Daily Assessments | |
| Thursday | Teacher | Student |
| AM | Teacher Session | Student Session |
| | Field Trips | |
| PM | Field Trips | |
| | Teacher lesson plan due | Analyzing research data |
| Friday | Teacher | Student |
| AM | Guest lectures | |
| | Field Trips | |
| PM | Guest Lectures | |
| | Lesson Presentation | Working on research presentation |
| | Post Assessments | |
| Saturday | Teacher | Student |
| AM | Project Presentation | |
| | Closing Ceremony, Guest Lectures, and Certificate Presentation | |


Figure 1. Hands-on activities

Figure 2. Teacher hands-on activities

B. Student and Teacher as Co-Learners

The DEAP program was a unique experiential learning program where secondary teachers and students were co-learners. During the DEAP program, teachers and students participated in discussions and heard lectures by experts who ranged from top management professionals in energy companies to technical experts in the field who primarily maintain energy infrastructure. Teacher and student participants were similarly exposed to cutting-edge research and technologies, machinery, and energy-generating mechanisms through hands-on activities, lab research, and power plant tours. DEAP also utilized senior teachers (those who had successfully completed the DEAP program in previous years) as mentors to the incoming teacher participants, who in turn served as mentors to student participants to facilitate the learning process. Teachers and students also had the opportunity to work together on group projects that focused on energy concepts, and teachers also learned to develop lesson plans by incorporating materials from the lectures, web resources, and books available during the program.

## 3. DEAP Assessment and Evaluation

A. Assessments

This study aims to describe the effectiveness of the DEAP program and addresses two general evaluation questions: (1) What impact did the program have on the participants? and (2) What are participants' overall perceptions of the program and what suggestions do they have for its improvement? Data for this analysis were obtained from pre- and post-assessment surveys administered to the participants during the week-long program. The post-assessment surveys consisted of open-ended and attitudinal rating scale questions.

Participants were made up of two separate groups: teachers and students. Due to the differences in survey question composition, group objectives, and educational levels of these two distinct groups, responses to the survey questions were quantified and discussed separately. Data for the survey consisted of both quantitative and qualitative portions. Analysis of the quantitative data was done using SPSS and includes descriptive statistics such as frequency counts, means, and proportions. Analysis of the open-ended qualitative portion was done by thematic coding using NVivo software. The themes from the participants' responses that emerged after the coding were then summarized.

B. Results

**1.** Perceived Program Benefit

Figure 3 displays the mean scores of student participants on the perceived benefit gained in five areas: (1) energy science knowledge gained, (2) inspiration, (3) social interaction, (4) energy citizenship aspiration, and (5) personal growth/development. Responses were reported in scores from 1 (strongly disagree on the program benefit) to 4 (strongly agree on the program benefit).

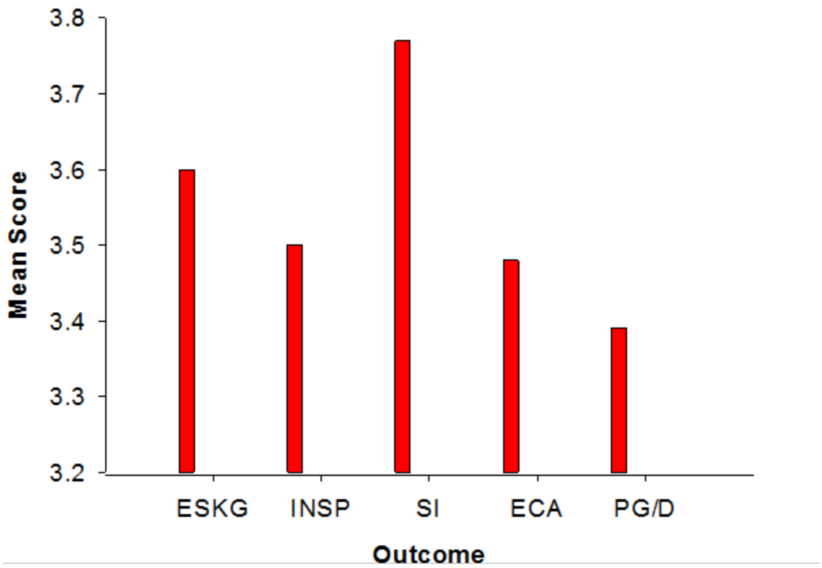


Figure 3. The mean score of student participants on perceived program benefits. ESKG = energy science knowledge gained; INSP = inspiration; SI = social interaction; ECA = energy citizenship aspiration; PG/D = personal growth/development

As Figure 3 indicates, the average scores ranged from 3.4 to 3.8, which suggests that most participants chose either "agree" (3) or "strongly agree" (4) in response to each of the five potential benefits to the DEAP program. The students' highest mean is 3.8 for social interaction, the perceived benefit of working and networking with teachers and fellow students in the program.

Additionally, in the post-assessment survey, students were asked to describe their perception of their interactions with the teachers who participated in the DEAP program activities alongside them. Students' responses described their reactions to getting to know teachers as people and fellow learners and learning about different teaching methodologies. One of the students described the teachers as "real people," "cool people," and another commented, "I learned that teachers are very fun, that they are easy with which to relate, and that they are interested in the same topics as students." Another student observed, "I learned that teachers are just like students and that they constantly want to learn. They always ask informative questions when they're confused and continue to have a curious nature." Regarding teaching methodology, a student explained: "I learned about various methods of teaching and school styles. For instance, I learned about a school where grades are not given and attendance is irrelevant."

Figure 4 presents the mean scores of teacher participants on measures of five main aspects of the DEAP program: (1) energy knowledge science gained, (2) knowledge gained for teaching energy science, (3) inspiration, (4) social interaction, and (5) personal growth/development. Responses to the questions were reported on a scale ranging from 1 (strongly disagree on the program benefit) to 4 (strongly agree on the program benefit).

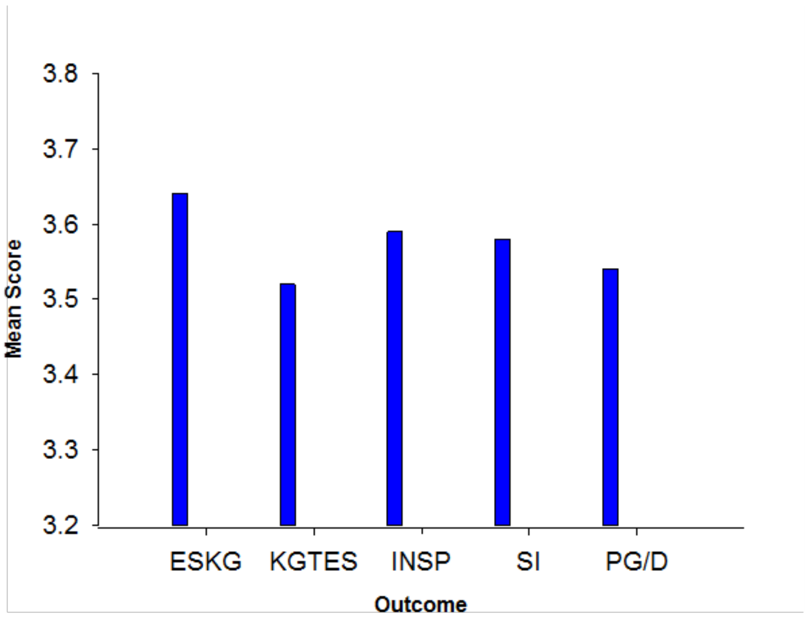


Figure 4. Mean scores of teacher participants on perceived program benefits. ESKG = energy science knowledge gained; KGTES = knowledge gained from teaching energy science; INSP = inspiration; SI = social interaction; PG/D = personal growth/development

Figure 4 shows the mean scores of teacher participants, which range from 3.5 to 3.65, indicating that most choose either "agree" (3) or "strongly agree" (score 4) for each of the five potential benefits of the DEAP program. The outcome "energy science knowledge gained" had the highest mean score (3.65).

Teachers further expressed their satisfaction with the knowledge they gained in energy science knowledge in their responses to the post-assessment survey. The following are three examples of teacher survey responses to the question of what was the most important lesson they learned from participating in the DEAP program:

"I learned about how the production of alternate energy isn't really as straightforward as it seems. I didn't understand why power companies were so concerned about alternate energy sources, but I understand now that it has to do with the stability of the grid. I gained a better understanding about new technologies like biofuel, nuclear energy and biomass."

"I feel I gained a lot of knowledge on energy. However, I may not be confident yet, but I will be. The coal plant and nuclear were the best for information for me. I gained not only information but explanations and actual pieces of the whole process that I didn't fully understand. I feel I have the ability to better explain those to students."

"How critical the energy industry is globally and how much awareness that needs to be raised about the various types of energy. I learned a lot about the energy types and the business behind the energy market. The most important lesson I learned was how critical it is that I teach my students about energy and energy careers and increase their awareness."

**2.** Program Activities

Figures 5 and 6 compare the percentage of student participants (Figure 5) and teacher participants (Figure 6) who reported each level of satisfaction toward DEAP program activities: hands-on activities, lectures, project activities, networking, and tours. Each colored bar indicates one of four different levels of satisfaction reported by participants.

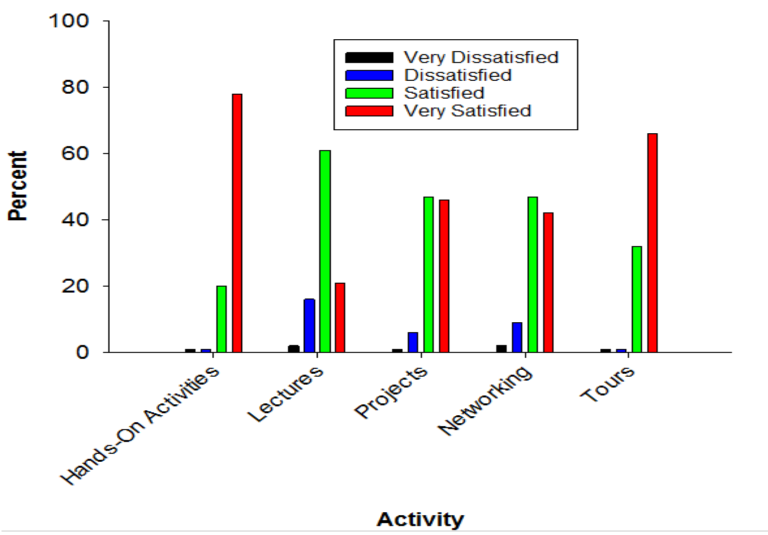


Figure 5. DEAP program activity student evaluation

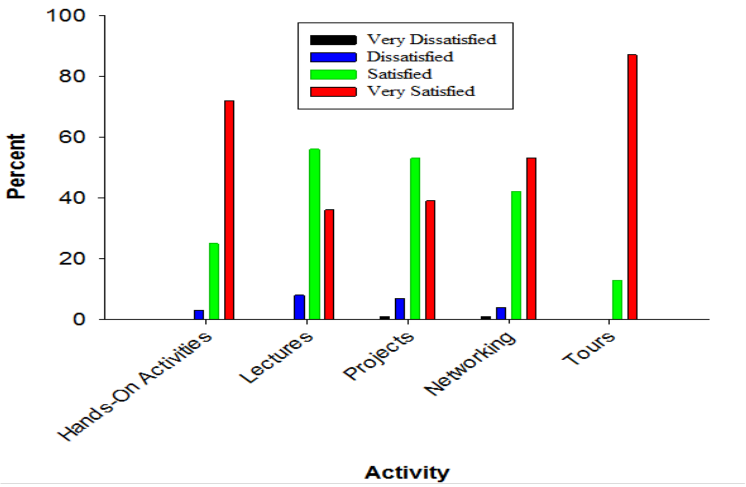


Figure 6. DEAP program activity teacher evaluation

Overall, the majority of both students and teachers were either very satisfied or satisfied with all types of activities in the DEAP program. Figures 3 and 4 show that the percentage of total participants' responses who appeared to be very satisfied and satisfied were approximately in the 80-90% range for students and the 90-100% range for teachers. Specifically, for both participants, the most well-received type of activity appeared to be hands-on activities and tours/field trips (more students were very satisfied with hands-on activities while a greater percentage of teachers were very satisfied with tours/field trips). In post-assessment questions, most teachers and students expressed the desire to have more time allocated for hands-on activities and tours.

One student commented, "I gained a vast amount of knowledge from hands-on activities." Hands-on activities were also reported to be inspiring by teachers, as evidenced by post-program comments such as, "I really learned how to problem-solve scientifically when we did the hands-on activity in making the blades of different wind turbines and testing them with fans. The activity inspired me to create lab experiments to solve scientific problems." Another teacher expressed enthusiasm about the educational value of the tours: "I learned a lot about how energy companies turn primary resources such as coal, petroleum, and wind into the secondary resource of electricity. It is fascinating to know how it actually works."

The lectures appeared to receive more dissatisfied responses from both participants (approximately 20% of students and 10% of teachers) than other types of activities. Further exploration through open-ended questionnaires revealed that students and teachers similarly struggled to maintain concentration to follow back-to-back lectures and would prefer lectures of shorter duration, fewer lectures, and more engaging and energetic lecturers. Participants also expressed difficulty understanding some of the more complex material and the technical terms and terminology used. Both teachers and students suggested that an additional overview of basic materials defining common terms would have helped them to better follow the lectures. At least one teacher, however, stated that they benefited from the diversity of the speakers' backgrounds: "Really, each lesson was beneficial—I learned so much. I learned from each speaker in a unique way as they shared their particular discipline."

## 3. Lessons Learned

The study results suggest that both the students and teachers preferred fewer lectures and more hands-on activities and field trips. While some teachers and students expressed their satisfaction with gaining diverse knowledge in multiple disciplines in energy science, they also struggled to maintain concentration during the lectures due to their long duration, the back-to-back lecture schedule, and the overly technical terminology used by the lecturers. Scheduling lectures is complex due to the busy schedules of invited professionals from business and higher education. And delivering lectures to high school students and teachers may provide a challenge to lecturers who have little previous experience with these types of audiences. Future programming might consider researching the most effective length for lectures to high school students and providing additional guidelines to lecturers on delivering content to an audience new to the lecture topic.

The responses of participants in this program suggest that an important component of learning about energy science is hands-on activities and field trips that provide direct engagement with technologies and observation of real-world systems. On the other hand, these often sophisticated and high-cost energy maintenance technologies are only available in limited quantities and require close expert supervision; thus, they are unlikely to be offered in traditional classroom settings. Afterschool energy science programs like DEAP that involve diverse expertise, professional speakers, and multiple activities can provide exposure to cutting-edge technology and up-to-date knowledge that is inspirational and beneficial to both teachers and students. Nonetheless, the program is limited in scale due to the substantial resources and detailed involvement required to prepare and organize the program.

Giving students and teachers the opportunity to interact socially as co-learners in hands-on activities and research projects allowed them to observe one another as learners. Additionally, teachers also gain insight into the student learning process that will potentially facilitate future lesson planning. We advocate for the design of afterschool programs that allow teachers and students to learn, interact, and work to solve problems together in similar learning spaces. Our findings suggest that afterschool programs can both effectively complement and expand on basic energy science knowledge currently provided in the traditional classroom setting, while also facilitating professional development of teachers by renewing and expanding the scope of their knowledge on current developments in the field of energy science.

## 4. Reflections

In addition to gaining insight from the DEAP program evaluation, the organizing committee reflected on several challenges that need to be considered in the process of program development and maintenance. One challenge is sustaining participant excitement throughout the program. Another major challenge is maintaining the necessary financial and human resources to produce similar afterschool programs. This includes organizing detailed procedures for advertising, recruiting participants, and communicating the program effectively to the university, industry partners, school officials, and parents. Another challenge is maintaining stewardship by the university, the industries, and the school partners that have provided the facilities and human and material resources to support this program over the years. In terms of targeting participants in minority populations, special effort is required to navigate delicate university procedures in engaging and protecting these groups.

## 5. Conclusion

The Duke Energy Academy at Purdue program was effective and successful in delivering energy science knowledge and inspiring interest in both teacher and student participants through multiple activities. Participants particularly found beneficial the experiential learning aspect of the program in the form of hands-on activities and tours of facilities. These experiences provided live engagement with facilities and technologies that are rarely experienced in traditional classroom settings. The DEAP specifically also provided a platform for teacher and student participants to be a co-learner. The opportunity to interact socially and professionally with one another allowed participants a means of gaining insight into each other's learning process. This social interaction appears to be meaningful to student participants due to the insight they gained into teachers as learning humans beyond the professional role that students typically experience of teachers in the classroom.

## 6. Acknowledgments

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