

Board 41: Developing Summer Research Programs at an NSF ERC: Activities, Assessment, and Adaptation

Maeve Drummond, CISTAR at Purdue University

M. Maeve Drummond, Assistant Director of Education for CISTAR, an NSF Engineering Research Center, has more than 20 years of experience managing academic programs for undergraduate and graduate students. She has worked extensively within the academic community and with external stakeholders. She implements the educational programs for university students, high school students and teachers that are central to the Workforce Development goals for CISTAR.

Dr. Monica E Cardella, Purdue University-Main Campus, West Lafayette (College of Engineering)

Monica E. Cardella is the Director of the INSPIRE Research Institute for Pre-College Engineering and is an Associate Professor of Engineering Education at Purdue University. She is also the Director for Pre-College Education for the Center for the Innovative and Strategic Transformation of Alkane Resources (CISTAR).

Dr. Maryanne Sydlik, Western Michigan University

Dr. Mary Anne Sydlik is a Research Emerita involved in the external evaluation of a number of federally funded projects.

Dr. Sydlik's interests are in supporting efforts to improve the educational experiences and outcomes of undergraduate and graduate STEM students. She is or has been the lead external evaluator for a number of STEM and NSF-funded projects, including an ERC education project, an NSF TUES III, a WIDER project, an NSF EEC project through WGBH Boston, two NSF RET projects, an S-STEM project, a CPATH project, and a CCLI Phase II project. She also currently serves as the internal evaluator for WMU's Howard Hughes Medical project, and has contributed to other current and completed evaluations of NSF-funded projects.

Kristin M. Everett, Western Michigan University

Kristin Everett is a research associate at the Center for Research on Instructional Change in Postsecondary Education (CRICPE) at Western Michigan University and conducts program evaluations and provides consulting services for education, health-care, and nonprofit organizations.

Developing Summer Research Programs at an NSF ERC: Activities, Assessment and Adaptation

Abstract

The focus of this poster is the educational programming and evaluation associated with an NSF Engineering Research Center (ERC). CISTAR, the Center for Innovative and Strategic Transformation of Alkane Resources, is a new NSF ERC in its second year. The center's mission is to create a transformative engineered system to convert light hydrocarbons from shale resources to chemicals and transportation fuels in smaller, modular, local, and highly networked processing plants. The center, a collaborative network of five universities, is supported by four pillars: workforce development, diversity, industry, and research. This poster will outline research experiences and career and graduate school preparation and associated evaluation related to workforce development and diversity including a Research Experience for Teachers (RET) for middle and high school teachers, a Research Experience for Undergraduates (REU) and a Young Scholars program for high school students. Our presentation documents and describes steps taken to launch the educational programming during the first year of the center.

The overarching broader impact goal of CISTAR Workforce Development is to create a technically excellent and inclusive community of hydrocarbon systems researchers, learners, and teachers. CISTAR aims to create an environment where people of all backgrounds are welcomed, supported, and respected.

The center engages an external evaluation team with extensive experience in evaluating STEM education programs, technology-based projects, professional development programming, and materials development projects. While the intensity and lengths of the summer 2018 programming varied, all participants engaged in key aspects of research (hypothesis development, experimental design, data collection and analysis, and communicating their results to others), were included in research meetings and presentations involving scientists at a wide-range of expertise (novice to mature), and had one on one mentoring with graduate students and other CISTAR program personnel. The external evaluators administered pre and post program surveys and mid-point interviews to both participants and mentors to collect formative feedback on the potential impacts of the project on the participants, graduate mentors, and to ask whether the goals and objectives were accomplished as planned, and identify strengths and limitations of the project. These evaluation strategies will be detailed as well as modifications to programming based on the results of this assessment.

Overview

The Center for Innovative and Strategic Transformation of Alkane Resources (CISTAR) is a National Science Foundation (NSF) Engineering Research Center (ERC) grant. ERCs are intended to integrate engineering research and education with technological innovation to transform national prosperity, health, and security. CISTAR's research goal is to create a transformative engineered system to convert light hydrocarbons from shale resources to

chemicals and transportation fuels in smaller, modular, local, and highly networked processing plants. CISTAR's Workforce Development goal is to create a technically excellent and inclusive community of hydrocarbon systems researchers, learners, and teachers through competency-based education, best-practice mentoring, and growth in key professional skills. Purdue University is the lead institution partnering with the University of New Mexico, Northwestern University, the University of Notre Dame and the University of Texas at Austin. The project began in fall 2017 and continues for five years, with the possibility of an additional five years of funding. A center wide team of faculty and staff direct the education programming for the center. This collaborative group meets twice a month to strategically outline university and pre-college objectives and implement programs.

Three summer programs were conducted in 2018: an eight-week (June 4 through July 27) Research Experience for Teachers (RET) program, an eleven-week (May 21 through August 3) Research Experience for Undergraduates (REU) program, and a six-week (June 21 through July 26) Young Scholars (YS) program.

Seven in-service teachers were recruited to participate in the RET summer program during which they were given the opportunity to come to Purdue University to engage in hands-on projects with CISTAR researchers and to create content for their classrooms. They implemented these lessons in their classrooms when they returned to school in the fall, revised their lessons and submitted reflections on the implementation back to the program leaders. While on campus, the teachers attended professional development sessions including workshops about engineering design, presentations about engineering majors and careers, and discussions about gender dynamics and STEM. Some had the opportunity to help Graduate Fellows with experiments at Argonne National Labs and all the teachers visited an industry partner to learn more about engineering careers.

Seven undergraduate students were recruited to Purdue for eleven weeks. In an effort to broaden participation, recruiting materials were distributed widely to minority serving institutions, schools without graduate programs, professional societies and agencies that support students with disabilities and veterans. The students were mentored by CISTAR Graduate Fellows on a designated research project.

Existing summer undergraduate research programs were leveraged so the REU students could attend workshops on: how to prepare for graduate school, securing funding for graduate school, and the benefits of graduate education. Eligible REU students were invited to participate in the "Pathways to Increased Diversity for Grad School and the Professoriate" program supported by the Purdue College of Engineering. Furthermore, these students networked with a broader group of students who were doing research in a plethora of research areas. In addition, the students visited Argonne National Labs and joined site visits to industry partners.

Ten high school students from the five center campuses were recruited to participate in the YS program that engaged them in a research group. Graduate Fellows were recruited to serve as mentors to the participants of the program at each campus. YS students and their mentors participated in a weekly video conference where they talked about assignments and were

introduced to libraries and other resources on their respective campuses. They also created a lit review, followed by a research abstract, and finally a poster to share in a poster session at their institution. All of the high school students also conducted an outreach event in their community and submitted a reflection on this activity.

Graduate student mentors for all of these groups were CISTAR Graduate Fellows, a group of student researchers who are being developed to understand their work’s impact on industry and the world by participating in professional development activities and a set of defined educational experiences. Mentoring university undergraduate students and high school students and teachers is a critical element of the CISTAR Graduate Fellow experience.

Evaluation

The evaluation for the programs was conducted by the External Evaluation Team from the Center for Research on Instructional Change in Postsecondary Education (CRICPE) at Western Michigan University. Evaluations were conducted at the middle of all three summer programs. Virtual interviews using ZOOM, a video conferencing service, were conducted with participants and mentors of each summer program. Each interview session was approximately 15 minutes long. The number of interviews is shown in Table 1.

| Program | Table 1. Number of Interviews | | | | |
|---------|-------------------------------|------------|---------------------|------------------|-------|
| | High School Students | Undergrads | In-Service Teachers | Graduate mentors | Total |
| RET | N/A | -- | 7 | 2 | 9 |
| REU | N/A | 7 | -- | 7 | 14 |
| YS | 10 | -- | N/A | 13 | 23 |

Interview questions centered around five themes:

1. **Successful Aspects.** “As your participation in the CISTAR Summer Programming has unfolded, which aspects have seemed to go smoothly and resulted in productive outcomes?”
2. **Problematic Areas.** “What areas have been problematic, and in what ways?”
3. **Suggestions for Improvement.** “What suggestions do you have for how to change/improve how the programming is being carried out?”
4. **Goals for the Second Half of the Program.** “What would you like to gain out of the remainder of your experience? If a mentor, what would you like the students to gain out of this experience?”
5. **Additional Comments.** “What else would you like to tell us about your experiences with the program?”

Results of mid-point evaluations included identifying successful aspects and areas to address. The successes included:

- The research experience was highly valued by the participants.
- Participants received helpful assistance and advice from the mentors.
- Mentors had a high regard for the participants and valued the time they were given to work with them.

Other reported successes included:

- **RET:** the opportunity to work on a poster, and practical applications for the classroom.
- **REU:** the good relationships undergraduates had with their faculty advisors and with others in the labs, weekly lunch meetings with the project director to express concerns and questions, and weekly breakfasts with faculty to learn more about their research projects.
- **YS:** learning about research resources on campus, becoming familiar with the campus, learning about the industry, and weekly meetings among all the participating universities.

Challenges and areas for improvement included:

- Most problems and challenges identified for the RET program occurred early in the summer and were addressed quickly and adequately.
- Several of the problematic area identified for the YS program were not related to the summer experience itself, but rather to the lack of background and young age of the participants.
- More significant challenges were identified for the REU program, mostly related to mentors and faculty advisors not adequately communicating or spending enough time with the participants.

After the mid-point interviews the program staff made a point to check in with the REU students to see if they were getting enough contact with their research mentors. In a few cases it was possible to ask an additional mentor to engage with the student.

Summative Evaluations

RET Program

CRICPE administered an online post-program survey to the seven in-service teacher participants on the last day of program (July 27, 2018). Items on the survey related to their experiences with the program and its impact on their teaching. Six of the seven participants stated that ***the program met or exceeded their expectations***. One explained, *“I feel that what I learned about engineering and research is directly applicable to my classroom.”* Another remarked, *“I hoped to walk away with many ideas on how to teach engineering and that has happened.”* The one who said their expectations were not met stated, *“I did not have any major expectations coming into the program.”*

All seven participants stated that ***they will be able apply what they learned or developed through the program to their classrooms or lessons:***

- *“I will implement a week-long module that will encourage both engineering standards and the state chemistry standards.”*
- *“I will use the results from my research experience to teach at least two concepts in my math classes. I will also expose my students to the engineering design process and use the co-created modules to expose my students to the different types of engineering pathways that are available to them.”*
- *“I am going to implement many more engineering design challenges in my physics classes.”*
- *“Lesson on combustion of gasoline. Lesson on catalytic converters.”*
- *“I am revamping my curriculum in order to give my students more opportunities to be exposed to engineering. I am designing activities that will teach my students how to collaborate.”*
- *“I would build a much stronger lab component to what I am doing. Lab sciences are crucial for student understanding. I would also have them conduct data analysis from data they have gathered.”*

Participants identified numerous ***“big Ideas” they learned from the program, the most common being the engineering design process.*** One teacher remarked that *“engineering is done right when, at the end, you have some kind of product or solution that can be used by people.”* Other “big ideas” included:

- We need more engineers from minority groups and women.
- Science is all about inquiry.
- Engineering is problem solving.
- Group work is a good way to have students learn.
- It is important to train students to think critically.

The primary challenge, reported by three of the participants, was a lack of background knowledge. One said, *“I hadn’t taken a General Chemistry course in years so I was a little clueless at several points in the program.”* Others challenges included:

A lack of organization at the beginning of the program.

- It wasn’t easy to directly apply the goals and research of CISTAR into the classroom.
- Personal challenges not related to the program.

REU Program

The following is a summary of the results of survey data collected from six (6) (pre-survey) and four (4) (post-survey) Summer 2018 REU participants. Of the six REU participants who

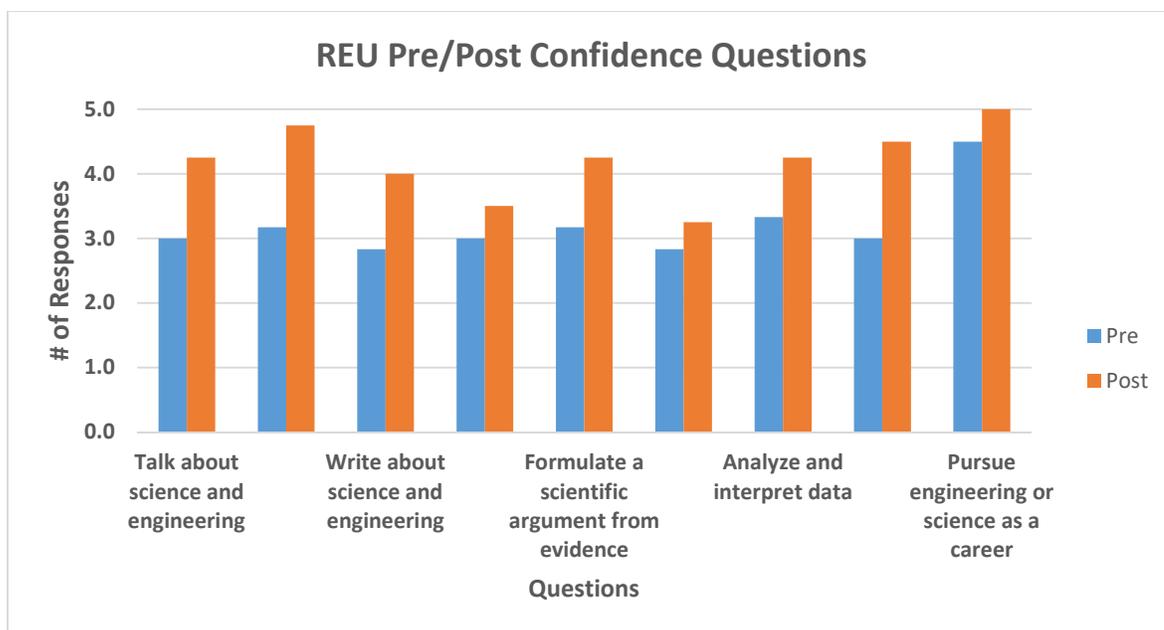
responded to the pre-survey, two indicated that they would be juniors and four that they would be seniors in Fall 2018. Participants completing the post-survey were evenly divided: two juniors and two seniors.

Participants provided a range of responses to the following question: *Complete the following statement by choosing the phrase that best describes your reasons for participating in the CISTAR REU program. Check all that apply. "I am participating because..."*

| | Pre | Post |
|---|-----|------|
| I am interested in learning more about engineering | 5 | 3 |
| I am interested in learning more about energy | 4 | 2 |
| I am interested in learning more about chemistry | 4 | 1 |
| I am interested in doing research | 6 | 4 |
| I want to go to graduate school in one of these fields and this experience will advance that goal | 6 | 1 |
| I am interested in pursuing a future academic research career | 4 | 2 |
| Other: I want to major in one of these fields in college and this experience will advance that | | 1 |

Participants also provided answers to the following series of questions: *Please rate your confidence in your ability to perform each of the following tasks on a five-point scale, with 1 = low confidence and*

5 = high confidence. There were not enough data to perform statistics, but the following graphic indicates improvement in participants' perceived confidence about doing each of the described tasks.



Young Scholars

Staff administered an online post-program survey to the twelve Young Scholar participants at the end of the program (July 2018). Items on the survey related to their confidence with scientific research and the impact of the program on their views of research. At the beginning of the Young Scholars summer program, participants were asked to rate their confidence in their ability to complete activities related to engineering research on a scale of 1-5, with 1 = Low Confidence and 5 = High Confidence. The nine activities they were asked to rate their confidence on were:

- a. Talk about science and engineering
- b. Read and use engineering and scientific literature.
- c. Write about science and engineering
- d. Generate a hypothesis
- e. Formulate a scientific argument from evidence.
- f. Design an experiment
- g. Analyze and interpret data
- h. Write a report based on an experiment.
- i. Pursue engineering as a career.

Participants were also asked about their confidence on these items on the post-survey administered at the end of the six-week summer program. Paired samples t-tests were performed to determine pre-to-post changes in their perceptions. Basic statistics are shown in Table 2. Three items showed a statistically significant change from the pre-to-post survey, suggesting *the program has some effect on participants' confidence about certain aspects related to engineering research.*

The items displaying a statistically significant change in participant confidence were:

- Talk about science and engineering
- Read and use engineering and scientific literature.
- Design an experiment

There was no change in participant confidence around:

- Analyzing and interpreting data
- Pursuing engineering as a career

| Table 2. Confidence Science and Engineering Research | | No. of Responses | | | | | n | Mean | SD | p-value |
|--|------|------------------|---|---|---|----|----|------|------|---------|
| | | 1 | 2 | 3 | 4 | 5 | | | | |
| a. Talk about science and engineering | Pre | - | 1 | 6 | 5 | - | 12 | 3.3 | 0.65 | 0.0116* |
| | Post | - | - | 2 | 9 | 1 | 12 | 3.9 | 0.51 | |
| b. Read and use engineering and scientific literature. | Pre | - | 1 | 7 | 4 | - | 12 | 3.3 | 0.62 | 0.0246* |
| | Post | - | - | 3 | 7 | 2 | 12 | 3.9 | 0.67 | |
| c. Write about science and engineering | Pre | - | 1 | 5 | 6 | 1 | 12 | 3.4 | 0.67 | 0.2750 |
| | Post | - | - | 5 | 6 | 1 | 12 | 3.7 | 0.65 | |
| d. Generate a hypothesis | Pre | - | - | 4 | 8 | - | 12 | 3.7 | 0.49 | 0.5036 |
| | Post | - | 1 | 2 | 7 | 2 | 12 | 3.8 | 0.83 | |
| e. Formulate a scientific argument from evidence. | Pre | - | - | 4 | 5 | 3 | 12 | 3.9 | 0.79 | 0.7227 |
| | Post | - | - | 2 | 8 | 2 | 12 | 4.0 | 0.60 | |
| f. Design an experiment | Pre | - | - | 7 | 5 | - | 12 | 3.4 | 0.51 | 0.0388* |
| | Post | - | - | 4 | 7 | 1 | 12 | 3.8 | 0.62 | |
| g. Analyze and interpret data | Pre | - | - | 5 | 6 | 1 | 12 | 3.7 | 0.65 | 1.0 |
| | Post | - | - | 6 | 4 | 2 | 12 | 3.7 | 0.78 | |
| h. Write a report based on an experiment. | Pre | - | 1 | 2 | 8 | 1 | 12 | 3.8 | 0.75 | 0.5863 |
| | Post | - | 1 | 3 | 7 | 1 | 12 | 3.7 | 0.78 | |
| i. Pursue engineering as a career. | Pre | - | - | 1 | 1 | 10 | 12 | 4.8 | 0.62 | 1.0 |
| | Post | - | - | 1 | 1 | 10 | 12 | 4.8 | 0.62 | |

* $p \leq .05$ is considered statistically significant

Summary

Overall the first summer of CISTAR research programs was very positive for both the participants and their graduate student mentors.

Recommendations for future years were largely operations and included the suggestion to pair teachers (and maybe REU students), providing more planning material in advance (schedule, assignment list, poster template), and sharing clearly defined roles for both mentors and mentees.

Improving the way participants are matched to projects was also recommended and could lead to greater satisfaction from the experience.

New ways to tie CISTAR research topics to classroom subjects are needed. An Outreach Committee of CISTAR faculty and staff is currently working on this project and may offer guidance for years.