Expanding Summer Research Programs at an NSF ERC: Innovation, Assessment, and Adaptation

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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.

Dr. Allison Godwin, Purdue University at West Lafayette

Allison Godwin, Ph.D. is an Assistant Professor of Engineering Education at Purdue University. Her research focuses what factors influence diverse students to choose engineering and stay in engineering through their careers and how different experiences within the practice and culture of engineering foster or hinder belongingness and identity development. Dr. Godwin graduated from Clemson University with a B.S. in Chemical Engineering and Ph.D. in Engineering and Science Education. Her research earned her a National Science Foundation CAREER Award focused on characterizing latent diversity, which includes diverse attitudes, mindsets, and approaches to learning, to understand engineering students' identity development. She has won several awards for her research including the 2016 American Society of Engineering Education Educational Research and Methods Division Best Paper Award and the 2018 Benjamin J. Dasher Best Paper Award for the IEEE Frontiers in Education Conference. She has also been recognized for the synergy of research and teaching as an invited participant of the 2016 National

Academy of Engineering Frontiers of Engineering Education Symposium and the Purdue University 2018 recipient of School of Engineering Education Award for Excellence in Undergraduate Teaching and the 2018 College of Engineering Exceptional Early Career Teaching Award.

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Abstract

The focus of this paper and poster is the educational programming associated with an NSF Engineering Research Center (ERC), the Center for Innovative and Strategic Transformation of Alkane Resources (CISTAR). CISTAR is entering its third year. This paper will outline programming and evaluation related to workforce development and diversity during the second year of the center including a Research Experience for Teachers (RET) for high school teachers, a Research Experience for Undergraduates (REU), and a Young Scholars program for high school students. We also describe the educational programming developed for an additional group of REU and RET participants as part of a supplemental NSF Research Experience and Mentoring (REM) project. These students and teachers engaged in the on-campus research program with CISTAR and then served as mentors at Summer Engineering Experiences for Kids (SEEK) camps led by the National Society of Black Engineers (NSBE).

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. The evaluators administered pre-, mid-, and post-program surveys to both participants and mentors to address the impact of the project on the participants, to ask whether the goals and objectives were accomplished as planned, and to identify strengths and limitations of the projects. These evaluation strategies will be detailed with special emphasis on the steps taken to modify the educational programming in response to evaluation findings from year one.

Center 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 designed to integrate engineering research and education with technological innovation to transform national prosperity, health, and security. 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.

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 new course and program offerings, best practice mentoring, and growth in key professional skills. CISTAR is designing an education program for its graduate and undergraduate students and creating programming for pre-college students and teachers to develop inclusive pathways to careers in STEM fields and intentionally prepare students to be leaders in the global energy economy.

To achieve a robust system of engineering education and pathways the Workforce Development team draws on an identity-based motivation theory to promote these skills and ways for all students (middle school to doctoral) to see themselves—identify— as active participants in the hydrocarbon workforce end.

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 2019:

- An eight-week Research Experience for Teachers (RET) program,
- A ten-week Research Experience for Undergraduates (REU) program, and
- A six-week Young Scholars (YS) program.

A supplemental NSF Research Experience and Mentoring (REM) grant provided support for a pilot program that engaged an additional three RET teachers and three REU students.

RET Program

Eight in-service teachers participated in the RET summer program for hands-on learning projects with CISTAR researchers and to create curricular content relevant to their learning projects for their classrooms. When they returned to school in the fall, they implemented these lessons in their classrooms, and sent their revised lessons and reflections on the implementation and its success back to the program leaders. While on campus, the teachers attended professional development sessions including presentations about engineering majors and careers, discussions about gender dynamics and teaming, specifically with CATME, a system of web-based tools that enable instructors to implement best practices in managing student teams. To help teachers connect design elements and projects with outreach to solve the needs of a community, teachers participated in a three-day Engineering Projects In Community Service (EPICS) K-12 workshop. Their session culminated in a poster presentation for CISTAR faculty, staff, and graduate students.

REU Program

Seven undergraduate students attended Purdue's ten-week REU experience. 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 veterans and students with disabilities. Publicity from the national headquarters of AIChE, the chemical engineering professional society, as particularly effective. More than 30% of our applicants learned about our REU opportunity this way. Our CISTAR graduate fellows were mentors to these REU students.

REM Program

We were able to add to our numbers of undergraduates and teachers because a supplemental NSF Research Experience and Mentoring (REM) grant allowed us to pilot a new program where an

additional set of REU and RET participants joined their respective cohorts. These students and teachers engaged in the on-campus research program with CISTAR and then served as mentors at Summer Engineering Experiences for Kids (SEEK) camps led by the National Society of Black Engineers (NSBE). In these camps, they worked with African American (and other underrepresented) elementary school-age children. The mission of SEEK is *"To increase elementary school students' aptitude in math and science and their interest in pursuing STEM (science, technology, engineering, math) career fields, by having them engage in interactive, team-based engineering projects."* This mission is aligned with efforts promoted by the CISTAR Workforce Development pillar and provided opportunities for REM participants to both learn about the research process as well as mentor others and be mentored themselves.

The undergraduates joined the REU cohort for research experience and professional development for six weeks before traveling to their assigned location of SEEK camp. The model was developed to provide an alternative to the traditional ten-week Research Experience for Undergraduates (REU) program which can limit a student's ability to engage in both a structured research program and a second summer experience that is socially and personally relevant.

YS Program

Thirteen high school students were recruited across the five CISTAR institutions to participate in the Young Scholars program. Each scholar was assigned a research mentor and a six-week research project. The scholars and their mentors participated in a weekly WebEx meeting with coordinators from all CISTAR institutions. The graduate student mentors led these sessions, and site education coordinators reviewed the assignments. The students created a literature review, followed by a research abstract, and finally a poster to share in a poster session at their institution and a five-minute WebEx presentation to their peers and graduate mentors. Finally, each scholar was required to plan and execute one or more outreach activities at a local school, library or science center and submit a summary of the activity and a reflection on their own experience. The YS program was a successful collaborative effort by Fellows and staff at all CISTAR campuses that developed synergy between the University Program and the Pre-College Program.

Program Mentors

Graduate student mentors for all of these groups were CISTAR Graduate Fellows, a group of student researchers who are supported through CISTAR to understand their 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.

Changes Made to Programs Based on Previous Evaluation

As the programs were developed for the second year of the center a series of design changes were made in response to evaluation results and feedback from participants in year one. The efforts from year one were reported in a previous publication [1]. These changes included improving communication before and after participants arrive on campus and providing background about the center and the plans for the program. Communication to mentees and mentors was coordinated to minimize confusion about program activities and expectations. A

structural change was made to prioritize placing two (or more) students or teachers in a given laboratory so they would have the benefit of having a lab mate who was also part of the cohort.

Also critical across the programs, formal graduate mentor training was provided to all graduate students as part of a center-wide Annual Meeting in May 2019. A mentoring award was presented to an outstanding 2018 mentor at the center-wide Annual Meeting. The award program is being expanded to recognize more students for excellence in mentoring.

In program specific changes, a "Chemistry Crash Course" was provided for RET and REU participants in week one, in response to feedback from 2018 teachers who asked for more background material.

The YS weekly meetings were designed to be more interactive with the addition of questions and exercises during the WebEx meetings. Additional strategies are being put in place for the 2020 session that will use another communication platform to further increase interaction between students at different sites.

Evaluation of Summer 2019 Programs

The External Evaluation Team from the Center for Research on Instructional Change in Postsecondary Education (CRICPE) at Western Michigan University conducted the evaluation of the programs. The purpose of the external evaluation was to determine progress toward project goals and objectives, identify effects of programming on targeted audiences, provide evaluative information for the management team to improve project efforts, and identify strengths and limitations of the project. The evaluation was framed by the following key questions:

- What progress has been made toward project goals and objectives?
- What have been the nature, extent, and quality of the project's education and career development programming to date?
- How were participants and their mentors affected by their participation in CISTAR?
- What are the strengths and limitations of the various components of the project?

The primary focus of the external evaluation has been to document activities, assess progress made toward meeting project goals, and evaluate project products and activities.

REU Program (includes REM participants)
REU participants completed pre/post surveys about their experiences with the program midway through the ten-week summer program. The surveys were administered at the beginning and end of the summer program. Below is a summary of participants' experiences based on an analysis of survey data.

How REU Participants Felt About the Program. On the pre-survey, all students (N = 9) stated that they were participating in the program because they wanted to learn more about engineering and eight (8) wanted to know more about careers in industry and were interested in doing research. All respondents (N = 9) indicated on the post-survey that their expectations had been

met. Eight stated that their career goals had changed including three individuals changed their long-term career goals from pursuing a master's degree to a doctoral degree.

What Worked. The evaluation indicated particular practices that were effective in developing Fellows' knowledge, skills, and abilities as well as identities during the program.

- Pre- and post-survey comparisons showed that REU Fellows felt they had made gains in their sense of themselves as researchers and leaders as shown in Figure 1. Their pre/post written responses to items asking about how CISTAR research can be important to the world and how engineering can benefit society and the world illustrate a maturation and depth of understanding gained by participating in this program.
- Fellows' written responses to the question, "How have you benefited..." were positive in the areas of how many people they had met and with whom they had been able to work. Students' also mentioned gaining networking connections; improved lab skills; stronger confidence in their research skills; and clarity about their futures as shown in Figure 2.
- Most Fellows indicated they would recommend the program to others.
- Survey responses showed that this set of Fellows had good relationships with their mentors, who they found helpful and motivated to help them.

Challenges and Recommendations for Improvement. The evaluation also revealed some opportunities for improvement of programs moving forward.

- The program leaders should start exposing participants to relevant background literature at the earliest possible time. As mentioned in the overview, staff sent background material about CISTAR to the participants in the form of articles and slide decks. Going forward, staff can include modules designed to show students how to approach reading and thinking about a journal article. The Chemical Engineering librarian led a face-to face session on using journal articles for the students when they were on campus. CISTAR staff have discussed having the librarian lead a similar session via WebEx before the students come to campus in future years.

Figure 1. Participants' sense of themselves as researchers. Both pre- and post-surveys asked students to indicate the degree to which they agreed with the following statements using a five-point scale, with 1 = strongly disagree, 3 = neutral or unsure, and 5 = strongly agree.

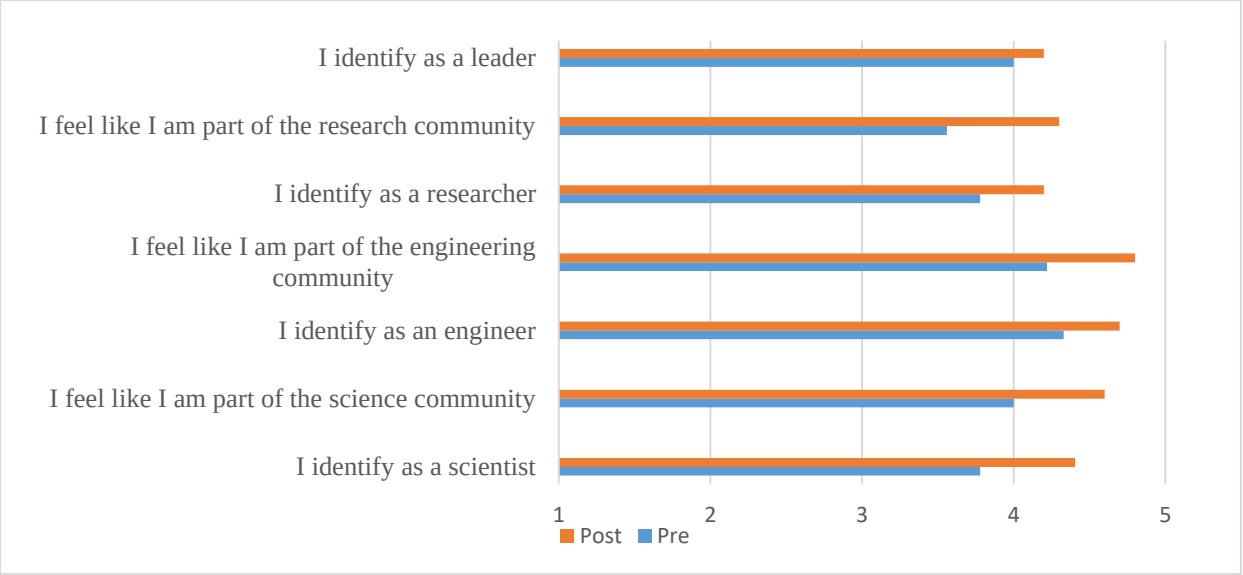
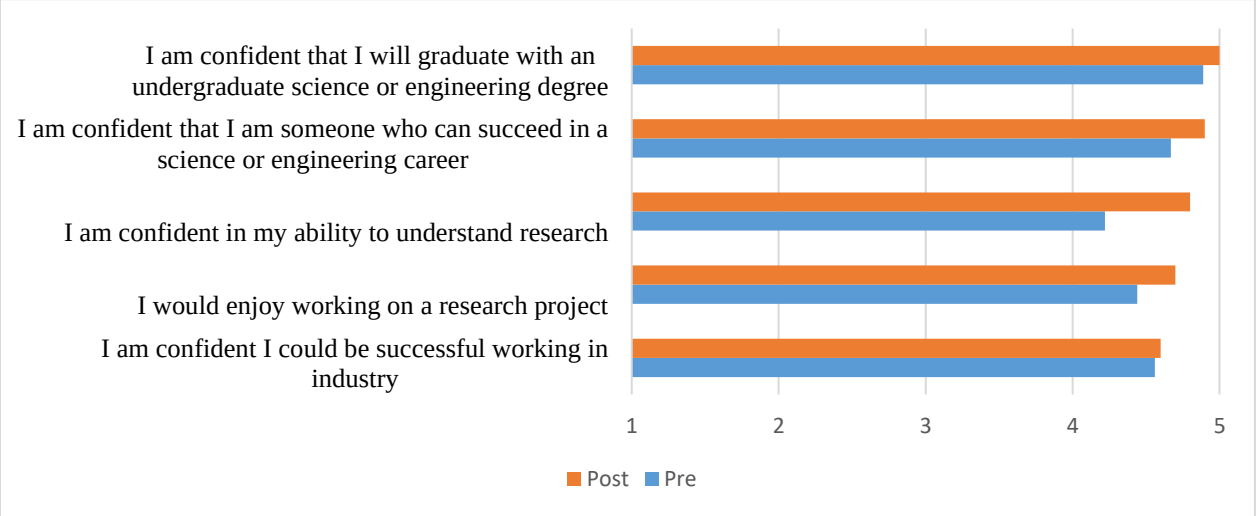


Figure 2. Fellows' confidence in pursuing engineering careers. Pre- and post-surveys asked participants to indicate the degree to which they agreed with the following statements using a five-point scale, with 1 = strongly disagree, 3 = neutral or unsure, and 5 = strongly agree.



REM (subset of REU and RET participants)

The goals for the REM summer experience were:

- Increase in knowledge and comfort of general research, CISTAR research, and lab safety
- Increase in knowledge and comfort on how to collaborate effectively with researchers from diverse backgrounds and inter-disciplinary areas
- Ability to design a technical poster and present it to the public
- Connect CISTAR research to SEEK by designing outreach activities for children at camp

The evaluation of the REM program was guided by the following key questions:

- What has been the impact of the program on REM participants, mentors, and the CISTAR leadership team members?

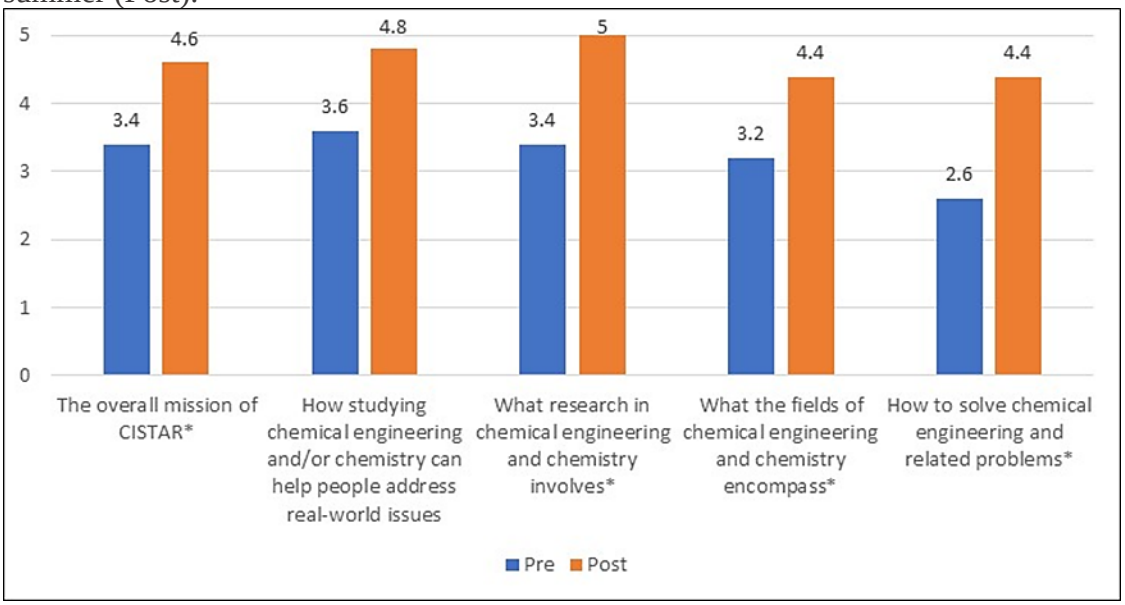
- Have the CISTAR REM Program's short, mid, and long-term goals and objectives been accomplished as planned?
- What are the strengths and limitations of the project?
- What has been learned about efforts to improve mentoring to enhance career or academic futures? How can these findings inform mentoring site programming on a national level?

The results of the evaluation indicated additional positive benefits of participation in the REM program. Participants identified the benefits of the program to include the pre- and post-survey results shown in Figure 3. The two undergraduates learned what it is like to be graduate students and do research. The three in-service teachers became "well-rounded" educators and learned how to convey chemical education to students.

All indicated they would recommend the program to others and that they gained useful knowledge and skills that fit their interests. All also indicated that observing and hearing about other teams' research activities helped them become better researchers and that working with their team members helped them improve their research skills.

The undergraduates felt it was useful to engage in weekly REU meetings, conduct literature reviews, write an abstract, and present a research poster. Most participants identified "big" ideas that they learned, including anything can be researched and studied, there is never only one answer to a question, the connection between problem-solving and innovation, and how to share difficult topics in a straightforward way.

Figure 3: Results of REM participants' self-reported evaluations of relevant knowledge of research practices and CISTAR content at the beginning of the summer (Pre) and end of the summer (Post).



RET Program (includes REM participants)

Eleven in-service teachers participated in the RET program at Purdue University. Seven (64%) were White, including four women and three men. Three (27%) were Black, including one man,

one woman, and one participant who did not specify a gender identification. One participant was a Native American man.

RET participants completed pre, mid, and post-surveys about their experiences at the beginning and end of the summer program. Below is a summary of participants' experiences based on an analysis of these data:

Satisfaction with the Program. Participants indicated a high degree of satisfaction with the program. They used words such as "amazing experience," "fantastic program," "most useful PD that I have had since beginning my teaching career," and "I loved it and am very indebted" on the post-survey to describe their experiences. One added "I look forward to next year, and [I am] hoping that I can come back for another time to continue what I was doing. It was great!"

All eleven participants indicated on the post-survey that the program met or exceeded their expectations. One wrote, "The program went beyond my expectations. The equipment used in the research were far beyond my experiences and offered an exceptional opportunity to grasp what's available to test scientific ideas." Ten (91%) indicated on the post-survey they would recommend the program to their colleagues.

Satisfaction with the Mentors. Participants expressed a high level of satisfaction with the mentors. They praised the mentors for being supportive of the program and for communication expectations and information clearly. This included one who said on the mid-survey, "[I had a] graduate mentor who was very organized and helpful, and let me observe and participate in research and assisted me with writing-related curriculum." None of the RET participants identified (either on the mid or post-survey) challenges or frustrations working with mentors, providing additional evidence of their satisfaction.

What worked. The evaluation indicated particular practices that were effective in developing participants' skills and future goals.

- Four participants reported that their educational/career goals changed from pre-to-post, including three who plan to incorporate more engineering or research into their classrooms and one who stated that their focus on engineering education has drastically increased
- Participants felt like they were part of the research community as a result of the program
- The program appears to have had some impact on respondents' ability to perform tasks related to teaching, including advising students about job opportunities in engineering areas, advising students about research opportunities to receive further training experience in science and/or engineering, using engineering design-based practices, and making presentations at in-service or professional meetings
- Participants were confident that the program would benefit middle and high school students because they will have participants who are more prepared or knowledgeable. They also felt and that their RET experiences will have a positive impact on their students' achievement
- RET Fellows gained knowledge and skills that fit their interests and were stimulated to think about ways to improve their teaching
- Respondents reported engaging the most in collaboration in research with an engineering faculty member and in reading scientific literature or journal articles

Challenges and Recommendations for Improvement. The evaluation also indicated opportunities to improve the program in the future.

- RET Fellows did not feel that they learned how to improve their lesson plans and teaching strategies. Since lesson planning was not the focus of weekly meetings until the final third of the program, there may not have been enough time to fine-tune the lessons. In addition, some of this work took place after the teachers left campus. More attention should be paid to this issue earlier in the summer program.
- The program appeared to have had little impact on respondents' overall views about science and engineering, but since they are, STEM educators this may not be surprising.
- Participants were most challenged by their lack of background knowledge and a lack of communication about the research they were to engage in. Program staff tried to address this issue by holding a two-hour Chemistry Crash Course interactive session during the first week of the program. However, it appears that additional strategies to provide background for participants need to implemented going forward.
- Some individuals felt they did not engage enough in designing and implementing their own investigations, and in planning and conducting outreach activities. The Young Scholars described similar challenges. There is a balance between completing independent research and being given a project that is manageable for such a short timeline.
- Only four Fellows reported having regular contact, either daily or multiple times a week, with the investigator leading the project. The remaining participants had contact with the investigator only once a week, less than once a week, or once in total.

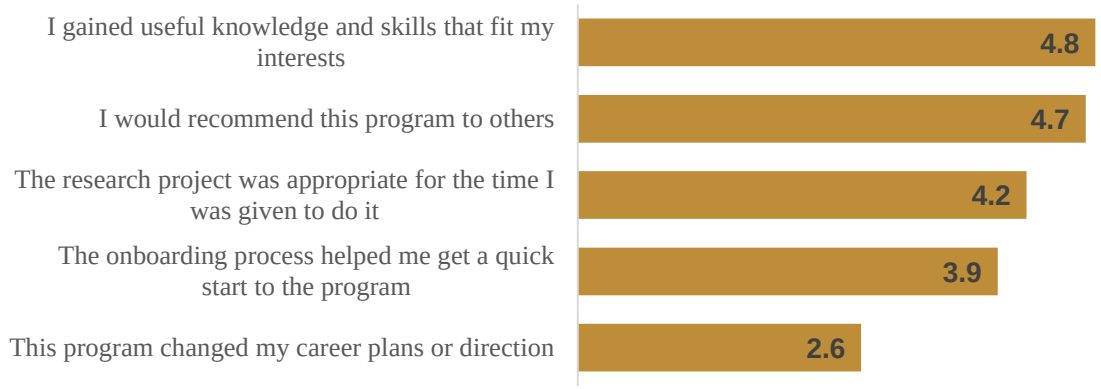
YS Program

Thirteen high school students were recruited across the five CISTAR institutions to participate in the 2019 Young Scholars program. We were unable to collect further demographic data on Young Scholars because they are minors.

What Worked. Similarly, to the RET and REU participants (described above), YS participants completed pre- and post-surveys. Below is a summary of participants' experiences based on an analysis of these data:

- *Satisfaction with the Program.* Young Scholars had an overall positive experience with the program, gaining valuable knowledge and skills and were likely to recommend the program to others (see Figure 4). Participants learned more about research, how research is conducted, and how they might incorporate research in their future educational goals and careers. At the end of the program, one participant commented, "I really enjoyed the program and thought it was a great way to spend the summer. It gave me confidence in my ideas to do research in college, and even opened up new ideas for me to pursue a degree in some sort of engineering field. Overall, doing research was exciting. Also, my mentor for the program was great and very knowledgeable about all things chemical engineering and beyond. I felt like I learned a lot about chemical engineering and many other topics and perspectives."

Figure 4: Results of YS participants post-survey about the program. On a scale of 1 to 5, with 1 = low and 5 = to a high extent, Young Scholars rated the following aspects of the summer program:



Less than half of the students (5 total) reported the Young Scholars program changed their long-term career plans. Most of the participants started the program planning to study engineering or medicine in college and reported they planned to continue those paths after their participation.

Challenges and Recommendations for Improvement. Areas that scored low on the participant surveys are areas the evaluation team felt that project leadership should revisit in future iterations of the Young Scholar programs. Those included:

- Students feeling like they designed and/or implemented their own investigation under supervision
- Improving onboarding process. Students were sent journal articles and slide decks
- Intensifying the review and discussion of research ethics at weekly meetings
- Increasing utility and importance of the weekly meetings
- Creating a deeper sense of community among the Young Scholars during the weekly meetings. As mentioned in the design-change section of the overview changes were made to improve these sessions and additional strategies are being explored for Year 3.

Summary

Participants from all four sets of summer programs indicated that they were highly satisfied with their experiences. A majority of REU students stated that their career and education goals had changed as a result of their CISTAR experience. All eleven RET participants indicated that the program had met or exceeded their expectations. Young Scholar participants indicated that they had learned more about research, how research is conducted, and how they might incorporate research into their future educational goals and careers. Likewise, all five respondents to the post-REM survey indicated that their expectations had been met, and four REM's indicated that their career goals had changed as a result of their summer activities. This overview of the CISTAR summer programs provides ways for others in the engineering education community to understand what was successful as a part of these summer programs how summer programs can continue to improve to develop participants' knowledge, skills, and abilities as well as identities and motivations.

References

1. Drummond Oakes, M., & Cardella, M. E., & Sydlik, M., & Everett, K. M. (2019, June), *Board 41: Developing Summer Research Programs at an NSF ERC: Activities, Assessment, and Adaptation* Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida. https://peer.asee.org/32344