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Lessons Learned from Evaluating Three Virtual Research Experiences for Teachers (RET) Programs Using Common Instruments and Protocols (Evaluation)

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Jennifer Blain Christen received a bachelor's degree (1999), master's degree (2001) and doctorate (2006) in electrical and computer engineering from Johns Hopkins University. Her dissertation focused on bioelectronics and microfluidics for life science applications exemplified through the development of a micro-incubator for cell culture. Blain Christen held a Graduate Research Fellowship and a G K-12 fellowship both from the National Science Foundation. In her postdoctoral work at the Johns Hopkins School of Medicine in the Immunogentics Department, she developed a microfluidic platform for homogeneous HLA (human leukocyte antigen) allele detection. Her research interests involve design of analog and mixed-mode integrated electronics for direct interface via innovative fabrication techniques to aqueous environments with special emphasis on biological materials.

Blain Christen is currently leading the BioElectrical Systems and Technology group at Arizona State University. The group has recently focused on flexible neural interfaces and point-of-care molecular diagnostics for underserved populations. She is primarily funded by the NSF, NIH, and CDMPR. Her research also has significant funding related to her startup, FlexBioTech.

Blain Christen serves on the Board of Governors for the IEEE Circuits and Systems Society, and she is president of the Biomedical Circuits and Systems Technical Committee. She also serves on the Diversity and Inclusion Initiative Taskforce at ASU.

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Lessons Learned from Evaluating Three Virtual Research Experiences for Teachers (RET) Programs Using Common Instruments and Protocols (Evaluation)

Abstract

Due to the COVID-19 crisis preventing face-to-face interaction, three National Science Foundation (NSF)-funded centers employed a virtual/remote format for their summer Research Experiences for Teachers (RET) Programs, reaching K-12 STEM teachers across the country. Teachers participated virtually from four different states by joining engineering research teams from four different universities in three different RET programs. Lab experiences depended on the nature of the research and institution-specific guidelines for in-lab efforts, resulting in some teachers conducting lab experiments with materials sent directly to their homes, some completing their experience fully online, and some completing portions of lab work in person on campus. Each teacher developed an engineering lesson plan based on the corresponding center's research to be implemented either in person or virtually during the 2020-2021 academic school year. Research posters, created with support from graduate student and faculty mentors, were presented to industry partners, education partners, center members, and the NSF. Support for the teachers as they implement lessons, present posters, and disseminate their developed curricula, has continued throughout the year. Common survey and interview/focus group protocols, previously designed specifically for measuring the impact of engineering education programs, were adapted and used to separately evaluate each of the three virtual programs. Strengths and suggested areas of improvement will be explored and discussed to inform future use of the common evaluation instruments. Additionally, preliminary results, highlighting general successes and challenges of shifting RET programming to a virtual/remote format across the three centers, will be discussed.

Introduction

In March of 2020 when many schools were closed for spring break, K-12 teachers across the country were pivoting to quickly convert all lessons to be delivered in a virtual/remote environment. Those teaching STEM subjects that typically require hands-on activities such as lab experiments, were even more in need for support during this transition. Although it may not have been realized at the time, building virtual STEM experiences for K-12 students can ensure reach to a wider audience, in addition to enhancing traditional, in-person settings by creating more interactive and engaging content [1].

Background

The National Science Foundation (NSF) funds several Research Experiences for Teachers (RET) programs across the United States that are designed to support teachers through authentic research experiences with engineering faculty researchers. One of the goals of the early RET program was to foster deeper involvement of K-12 and community college faculty in engineering research with the intention that faculty would bring this knowledge to the classroom promoting student interest in engineering fields [2]. Prior to 2007, RET programs focused primarily on teacher participants' observations of engineering research; however, a shift occurred in 2007 leading to increased alignment between RET research experiences and classroom learning. Teachers engaged in hands-on research with the hope that they would translate that experience to their classrooms.

One important expectation for NSF-funded centers is to build effective, long-term partnerships with pre-college institutions. These partners (e.g., K-12 schools, community colleges, ongoing programs) commit to working with the center by encouraging their STEM teachers to participate in an RET program. These experiences, which are traditionally held in person, provide K-12 STEM teachers and community college STEM faculty with the following: 1) engineering research experiences in center research labs, 2) guidance in developing engineering content curricula based on center research, and 3) follow-up support for translating research experiences into classroom practice [3]. Sustained follow-up with the teachers throughout the academic year, in addition to a plan for evaluating program impact are also included in the program.

In K-12 classrooms, engineering education can prepare learners to use higher-order thinking strategies in order to solve ill-structured, real-world problems [4]. Engineering relies primarily on problem solving; engineers seek to solve problems that present in many forms and contexts [5], [6]. Due to the ill-structured nature of the engineering problem-solving process, learners benefit from modeling, authentic learning problems and contexts, which teachers who have hands-on research experience are better equipped to provide [6], [7]. The RET program offers teachers the opportunity to have that hands-on research experience.

To assess progress and accurately measure the impact of an RET program, each center is expected to include a comprehensive evaluation plan, including both formative and summative assessments, which is then conducted by an external evaluation group. Feedback from assessment is then provided to the center in order to improve various aspects of the RET program each year. Although all RET programs have similar structures, the evaluation tools used, such as survey instruments and interview protocols, have been developed in isolation. In an effort to streamline the evaluation process across centers, a consortium of education leaders and evaluation teams from three NSF-funded Engineering Research Centers (ERCs) have been working together to develop an inventory of assessment instruments [8]. These common instruments, which were modified to include items addressing virtual components of the program, were used by each of the three different RET programs discussed in this paper.

Purpose of Study

During the summer of 2020, three NSF-funded centers modified their existing RET programs in order to provide research experiences for K-12 STEM teachers across the country during the COVID-19 pandemic. The research focus for two of the programs (Precise Advanced Technologies and Health Systems for Underserved Populations (PATHS-UP) and Sensor, Signal and Information Processing (SenSIP)) centers around computer science and machine learning, which lends itself to a virtual environment. However, the research focus for the third program (Center for Bio-mediated and Bio-inspired Geotechnics (CBBG)) is mostly lab-based and required additional options for delivering an authentic experience for the teachers [9]. The process for designing and converting each program to an online format was carefully considered to ensure effective delivery. Using a summative and formative evaluation approach, each center's RET program was evaluated to measure overall program impact, as well as the participants' experiences in the new virtual format.

The two primary goals of this paper were to: 1) evaluate the shift from a traditional, in person RET program to a hybrid/virtual environment, and 2) compare the use of common instruments across three different RET programs.

Program Format

Center for Bio-mediated and Bio-inspired Geotechnics (CBBG)
In response to COVID-19, the 2020 CBBG RET Program was modified and delivered in a hybrid format to better provide support for teachers adapting STEM-focused and lab-based engineering lessons for online and remote delivery. Teachers worked with researchers from Arizona State University, Georgia Institute of Technology, and Primarily Undergraduate Institution (PUI) partner, Lafayette College. The program has resulted in a newly developed five-week course with asynchronous elements in a Learning Management System (LMS) and weekly synchronous components via Video Conferencing (VC). Each weekly module in the LMS focused on a different theme: 1) Program Orientation, 2) Conducting Center Research/Curriculum Development, 3) Engineering Education Standards/ Developing a Problem-based Engineering Lesson, 4) Adapting Engineering Lessons for Remote/Online Teaching, and 5) Presenting and Writing about Scientific Research (see Table 1 for detailed program agenda).

Table 1. *CBBG Hybrid RET Program*

Week	Topics	Asynchronous (LMS)	Synchronous (VC)
1	Program Orientation	• Orientation module • Program overview • Required trainings • Knowledge Check	• Welcome • Intro to RET program • Research presentations • Q&A
2	Conducting Center Research/ Curriculum Development	• Research/ Curriculum Dev. module • Center research projects • Lesson plan expectations • Knowledge Check	• Curriculum development • Research presentations • Industry presentation • Strategies for online labs
3	Standards in Engineering Education/ Developing a PBL Engineering Lesson	• Standards/ PBL module • PBL in engineering education • K-12 engineering standards • Knowledge Check	• Curriculum development • Engineering ed. standards • PBL in engineering education
4	Adapting Engineering Lessons for Remote/Online Teaching	• Remote teaching module • Online vs. crisis teaching/ learning • Universal Design for Learning • Knowledge Check	• Curriculum development • Minoritized women in STEM • Adapting an engineering lesson for remote delivery
5	Presenting and Writing about Scientific Research	• Dissemination module • Writing scientific research • Tying research to curricula • Knowledge Check	• Curriculum development and presentation help • Research/lesson presentations • Closing activities

Teachers participated in the weekly Discussion Board assignments and submitted all materials (lesson plan, presentation, poster, implementation report, etc.) in the course. At the end of each module, teachers completed a brief Knowledge Check and Weekly Update within the LMS. The course format was used as a model for other RET programs and portions will again be included in the RET program next summer, even if the program is held in person.

In addition to the virtual components of the program, each CBBG teacher also participated in a mentored lab component. The teachers' lab experiences varied based on the individual campus situation. Participants that were able to come to campus and follow the university's COVID-19 guidelines completed some or all the lab portion during the summer. Other teachers were mailed lab materials so they could set up and conduct experiments at home. One of the Georgia Institute of Technology teachers, who happens to be employed at a K-12 cyber academy, was very familiar with teaching at a distance and comfortable conducting research at home (in her case, it was with 150 ants)! Another teacher, who lives in a rural part of the state and three hours from the Lafayette College campus, was sent an entire lab set up with inexpensive materials to use. The exact same equipment, other than the local tap water used, was also sent to the undergraduate students on the research team so results could be compared across various parts of the country.

Precise Advanced Technologies and Health Systems for Underserved Populations (PATHS-UP)
The PATHS-UP RET program at Rice University provided six teachers a virtual internship where they could learn about using computer science and machine learning to improve the detection and treatment of diseases and to develop grade level appropriate lesson plans based on their experiences. The five-week program consisted of teachers conducting team-based research, weekly meetings with graduate student mentors, reviewing journal articles, attending professional development meetings, and building scientific written and verbal communication skills. The weekly themes were 1) Orientation, Literature Review and Introduction to Python, 2) Introduction to OpenCV and Basics of Computer Vision, 3) Introduction to Machine Learning, 4) Implement the Monitoring, and 5) Analyzing Data, Developing Lessons and Research Presentations (see Table 2 for detailed program agenda).

Table 2. *PATHS-UP Virtual RET Program*

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1 June 15-19	• VC Orientation • Lesson Building & Independent Research	• Lesson Building & Independent Research • Graduate Student Presentations	• Lesson Building & Independent Research • Faculty Talk	• Lesson Building & Independent Research • Graduate Mentor Meeting	• Lesson Building & Independent Research • *Blog Post* • Timesheet Due
Week 2 June 22-26	• Lesson Building & Independent Research • Weekly R-STEM Meeting	• Lesson Building & Independent Research • Graduate Student Presentations	• Lesson Building & Independent Research • TeachEngineering Talk	• Lesson Building & Independent Research • Graduate Mentor Meeting	• Lesson Building & Independent Research • *Blog Post* • Timesheet Due

Week 3 June 29-July 3	• Lesson Building & Independent Research • Virtual Poster Training • Diversity Training	• Lesson Building & Independent Research • Graduate Student Presentations	• Lesson Building & Independent Research • Graduate Mentor Meeting • *Blog Post*	OFF DAY	OFF DAY
Week 4 July 6-10	• Lesson Building & Independent Research • Weekly R-STEM Meeting	• Lesson Building & Independent Research • Graduate Student Presentations	• Lesson Building & Independent Research • Faculty Talk	• Lesson Building & Independent Research • Graduate Mentor Meeting	• Lesson Building & Independent Research • Poster Draft Due • *Blog Post* • Timesheet Due

Sensor, Signal and Information Processing (SenSIP)
The SenSIP center's RET program was proposed in 2019 to engage teachers and community college faculty in face-to-face sessions. However, because of the COVID-19 conditions the program was run virtually with a small group of teachers. The program was funded in February 2020 and after mid-March 2020 the decision was made, after permission from NSF, to run the program using entirely online tools. Due to the solely online nature of this year's program, online tools became necessary and a clear organizational strategy was required for coherence. Arizona State University's LMS of choice was used for the overall management and structure of the program, with strong use of modules and pages for organization. Six modules were defined at the beginning of the program and content pages added as needed to construct an organizational hierarchy. These following modules were included: 1) Resources, 2) Research Project, 3) Machine Learning, 4) Project Updates, 5) Sensors and Machine Learning Videos, and 6) Meeting Agendas and Notes. Each live presentation, recorded video, meeting, and assignment was organized and added to the LMS. The calendar and all resources created or used during the RET were posted, along with all teacher materials, presentations, posters, and reports to maximize project coherence and organization.

The RET was divided into two daily elements - the synchronous and asynchronous components. Typically, the teachers spent the morning working synchronously with the graduate mentor in live VC sessions and the afternoons working asynchronously on their individual projects and watching pre-recorded videos and other materials. VC meetings began at 11:30 am and persisted for one to two hours as illustrated in the partial schedule shown below in Table 3.

Table 3. *SenSIP Virtual RET Program*

	Monday	Tuesday	Wednesday	Thursday	Friday
WEEK 1 May 25-29	Memorial Day	• Preparations • Access to RET LMS	• Intro - Center Research • Kick off meeting • Q&A • Wk. 1 Module: Orientation	• Complete trainings • Safety • IT Training • Wk. 1 Module: Orientation	• Intro to Python • First 3-slide report • Abstract Proposal • Wk. 1 Module: Orientation

WEEK 2 June 1-5	• Python for ML • Wk. 2 module • 1-page Abstract • SensMACH Seminar • ML Training Seminar	• Python for ML • Week 2 module • Submit Abstract • SensMACH Seminar • ML Training Seminar	• Python for ML • Week 2 module • Abstract Feedback • SensMACH Seminar • ML Training Seminar	• Python for ML • Week 2 module • Finalize Abstract • SensMACH Seminar • ML Training Seminar	• Intro to Solar • 3-slide report • Submit Final Abstract • SensMACH Seminar • ML Training Seminar
WEEK 3 June 8-12	• Python for ML • Python ML for Solar Data • Wk. 3 Module: PBL in engineering • SensMACH Seminar	• Q&A session • Python ML for Solar Data • Wk. 3 Module: PBL in engineering • SensMACH Seminar	• Python for ML • Python ML for Solar Data • Wk. 3 Module: PBL in engineering • SensMACH Seminar	• Python for ML • Python ML for Solar Data • Wk. 3 Module: PBL in engineering • SensMACH Seminar	• Intro to Solar • 3-slide report • Q&A for wk. 3 • Wk. 3 Module: PBL in engineering
WEEK 4 June 15-19	• Lesson Plan Session • Begin Work on Poster • Wk. 4 Module: remote/online lessons • SensMACH Seminar	• Lesson plan development • Work on Poster • Wk. 4 Module: remote/online lessons • SensMACH Seminar	• Check-in & lesson help sessions • Lesson plan development • Wk. 4 Module: remote/online lessons • SensMACH Seminar	• Lesson plan development • Wk. 4 Module: remote/online lessons • Work on Poster	• Adapting an engineering lesson plan during for remote delivery • Progress report • Wk. 4 Module: remote/online lessons • Work on Poster
WEEK 5 June 22-26	• Lesson presentation help session • Submit poster • Wk. 5 Module: Presenting & writing scientific research • SensMACH Seminar	• Feedback on Poster • Wk. 5 Module: Presenting & writing scientific research • SensMACH Seminar	• Check-in & lesson help session • Python for ML & Energy – Lessons • Submit poster ver. 2 • Wk. 5 Module: Presenting & writing scientific research	• RET lesson plan presentations • Lesson plan development • Feedback on Poster • Wk. 5 Module: Presenting & writing scientific research	• RET lesson plan presentations • Submit Lesson Plan and Poster • Closing Session

Methods

The rapid spread of COVID-19 in early 2020 allowed faculty and administrators very little time to pivot RET programming from a planned in-person program to a fully virtual or remote experience. It was important to consider program content and methods of delivery for effective online teaching and learning. Evaluation efforts were also adjusted to ensure that successes and opportunities for growth could be examined within this novel format. Given the quick shift to virtual, it was critical for evaluators to rely on formative evaluation to explore how the program format impacted participants' experiences and to inform the evolution of virtual or hybrid RET programming. Weekly updates from program participants were used to address any issues that arose during the program and to modify programming, as needed. Traditional summative evaluation was also used to assess impacts of the RET programming on skill-building and knowledge generation.

Evaluation findings from each center were discussed with leadership and used to make data-driven decisions about RET programming for summer 2021 and beyond. Leadership used evaluation data to decide if virtual or hybrid RET programming would again be offered in future years and how to adapt the RET program for optimal delivery in a virtual format. Findings and best practices were also shared with other program decision makers at the NSF ERC Education Leaders Group monthly meeting.

Participants

CBBG

Eight K-12 STEM teachers were selected from a pool of 30 applicants, including four teachers at Arizona State University, three teachers at Georgia Institute of Technology, and one teacher at CBBG PUI partner, Lafayette College. Participants were recruited from local CBBG educational partners, which all serve students from populations traditionally underrepresented in engineering. Two participants teach in a Title 1 school district in Phoenix, one teacher was transitioning back to the classroom from the Arizona Science Center, and two teachers were part of an NSF-funded project to develop criteria and associated metrics for K-12 engineering educators with the needs of their students in mind. The teachers themselves also represented diverse backgrounds. Four of the participants identified as African American, one also identified as Asian American, and another teacher identified as Native American. Six of the participants taught at the middle school level and two taught at the high school level.

PATHS-UP

With a short two-week application window, 42 applications were received from 19 unique school districts. The teachers selected for the program teach in schools in high needs school districts in the greater Houston area including IDEA Montopolis (IDEA Public Schools), Spring Woods High School (Spring Branch ISD), Hogg Middle School (Houston ISD), Dulles Middle School (Fort Bend ISD), and Blanson CTE High School (Aldine ISD). To compare the virtual format to the face-to-face experience, two of the 2020 participants had completed the 2019 traditional RET. The teachers were diverse with three identifying as Hispanic, 1 African American, and 1 Asian.

SenSIP

The SenSIP RET program was awarded in February 2020 as a limited submission NSF program with an initial plan for nine teachers and community college faculty. Due to COVID-19 uncertainty, recruitment was postponed until permission was obtained from the RET program manager in late April and reduced to only two teachers in an online environment. On very short notice, 15 applications were obtained, and two teachers were offered a position. One teacher self-identified as African American and the other preferred not to answer the application question regarding race. Both teachers work at disadvantaged Title 1 schools in Arizona, along with serving as adjunct faculty at their local community colleges, which have been federally designated as Minority Serving and Hispanic Serving Institutions. While the teacher based in the Phoenix area had participated in a previous RET program, the teacher from the Tucson area had not, and strongly benefitted from the online nature of the program, being in a rural part of the state approximately a two hour drive from the university. Reference materials created by the teachers will be disseminated once final.

Data Collection

Surveys were distributed electronically to RET participants in August 2020 immediately following the completion of RET programming. Focus groups were also scheduled in August 2020 after the survey was closed. Fourteen of fifteen teachers completed the survey and participated in a focus group (response rate = 93%). Frequencies were used to examine quantitative data due to the small sample size. Focus group data were analyzed using inductive thematic analysis.

Additional data was collected throughout each of the programs to inform future RET experiences, especially those provided in a virtual format. Some participants were required to submit a weekly update on the lab experiences component with their mentors, while others gave a brief research presentation updating the team on their progress each Friday. All participants developing a research poster and presenting a final overview of their lesson were provided templates and evaluated through observation and document review.

Online Survey

After reviewing each of the survey tools created and used by three different centers, items were compared and grouped by category before synthesizing into one common instrument. As the online survey is general enough for all center participants (graduate students, undergraduate students, high school students, teachers, etc.), a small set of additional questions specifically addressing RET outcomes are added for this subset of research participants. Furthermore, questions specific to the exclusive virtual environment due to the COVID-19 pandemic were added to this summer's instrument. Survey subsections included: Understanding of the Center, Communication and Research Skills, Mentoring, Teaching/Lesson Plan Development, Culture of Inclusion, Program Satisfaction, and Remote Teaching/Virtual Programming. These various subsections are listed and described in Table 4, along with indication of which questions were included for each center.

Table 4. *Subsections of Survey Items*

Subsection	Description	CBBG	PATHS-UP	SenSIP
Understanding of the Center*	Items related to participants' perceived understanding of the ERC (e.g., mission of the ERC, primary field(s) involved in the ERC, connection between ERC field(s) of study and how the ERC helps people address real world issues, engineering problems associated with the ERC field(s) of study, and career pathways(s) associated with the ERC's field(s) of study) * Specific to an NSF ERC, not asked of SenSIP participants	X	X	

Communication and Research Skills	Items related to the level at which participants perceived their center to impact communication skills (e.g., communicating orally/visually, networking, collaboration) and research skills (e.g., formulating research questions, analyzing data, interpreting results)	X	X	X
Mentoring	Items related to the teachers' perceptions of what their mentors provided (e.g., advice that supports their future plans, direction on their research project, training to support independent work, constructive feedback, encouragement to strive for success, and inspiration to pursue a career in a STEM-related field) and to what extent their mentors: demonstrated knowledge, established goals, served as a role model, and challenged them to extend their abilities.	X	X	X
Teaching/Lesson Plan Development	Items related to teaching STEM and developing lessons in terms of teachers' perceptions of their: preparedness to develop a lesson related to the center's field of study, incorporating engineering concepts into the classroom, exposing students to opportunities in the center's field of study and engineering, and helping students gain the skills they need to pursue a career in engineering.	X		X
Culture of Inclusion	Items related to asking teachers the extent to which they have observed diversity and inclusion as a valued component of the center and been treated fairly and respectfully.	X	X	
Program Satisfaction	Items related to asking the extent to which teachers would consider applying to be in another center's summer program, if they would recommend others to participate in an RET summer program, and recommendations for improvement	X	X	
Remote Teaching/Virtual Programming	Items related to asking the extent to which the training needed to develop remote lesson plans and implement the lesson plan remotely was sufficient, in addition to challenges and barriers	X	X	X

Interview/Focus Group Protocol

At the time of data collection, qualitative instruments were under development by the consortium, including a protocol appropriate for use in an individual interview or focus group setting. Three questions from the protocol were asked across all three centers. Specifically, teachers were asked to describe anything that was helpful in 1) developing their lesson plan and 2) preparing them to implement their lesson plan (PATHS-UP also asked for recommendations to improve these aspects of the program). Additionally, all teachers were asked if there was "anything else you would like to share?" Questions regarding the virtual format of the program were also added to each protocol. The only common question related to the virtual format asked teachers to identify ways that virtual RET programming could be strengthened in the future. Specific to PATHS-UP, participants were also asked the following:

- For those of you who have participated in a PATHS-UP program before, how did this summer's experience compare to the last? What was the same and what was different?

- What aspects of the RET program worked well using the virtual/remote format and why?
- What aspects of the program were challenging due to the virtual/remote format? Why?
- Did you have any challenges participating in the RET program due to problems with technology or lack of access to a computer or distraction-free workspace? Please explain.
- How, if at all, was receiving support from others (peers, mentor) impacted by participating in a virtual/remote format?
- What recommendations would you provide to improve the virtual/remote aspects of the program?
- Are there any additional information, tools, or resources that you think would be helpful in future virtual/remote iterations of this program? Please explain.
- One of the PATHS-UP ERC's objectives is to "create a PATHS-UP community." Can you suggest any ideas for this virtual RET program to help foster this sense of community?
- Do you have any recommendations for improving the communication channels or platforms used within the virtual RET program?

Additional Data Collected

With the lab experiences mostly or entirely in a virtual format, it was necessary to collect additional data throughout the program to ensure participants were receiving the expected support from their mentors. CBBG required teachers to submit a weekly update on the projects and mentor interactions in the LMS at the end of each week. The same four questions were asked each week: 1) What did you and you mentor discuss this week?, 2) What did you accomplish this week?, 3) What do you plan to accomplish next week?, and 4) Please discuss anything interesting you experienced this week, additional updates not previously captured, or what help you need from the RET program. Teachers in SenSIP were asked to prepare and present a brief research update (1-2 slides) each Friday to the research team. These weekly presentations, which included research updates, curriculum goals, and next steps, were uploaded by the teachers in the LMS for evaluation.

During the final week, all participants presented a final overview of their developed lesson plan based on center research. Feedback was given from center researchers, mentors, and teachers participating in another RET program. The weekly updates and final presentation also served as resources as the teachers developed their research poster. Deliverables were evaluated through observation and document review by each center's education team and external evaluator.

Results

The data from the survey and focus group instruments was utilized to summatively assess the impact of the centers' educational programming. Developmental and formative components of the evaluation also generated recommendations to inform modifications for improved future programming.

The primary purposes of this paper are to evaluate the shift to a virtual format for RET programming and to compare the use of the common evaluation instruments across centers. The data from the survey and focus group instruments was utilized within each respective center to assess the impact of the centers' educational programming. Formative components of the evaluation also generated recommendations to inform modifications for improved future programming. To avoid drawing comparisons across RET programs, a general overview of findings from the three centers' summative results are reported, including impacts related to research and communication skills, lesson plan development, and mentoring. A sample of quantitative and qualitative findings are included in the sub-section below.

Shift to Virtual Format

Overall, results indicate that the RET programs were largely successful in their meeting educational objectives using a new virtual format. Findings show that the RET programs impacted teacher's knowledge, understanding, and research and communication skills. After the program, teachers reported preparedness to implement engineering concepts into their classrooms and some noted how the virtual RET experience helped better prepare them to teach virtually in the upcoming semester. The majority (> 60%) of RETs reported high levels (i.e., 4 or 5 on a 5-point scale) of impact on various research and communication skills. Furthermore, at least 96% of the RETs also reported that same level of impact in their ability to develop lesson plans that were aligned with their centers' research. An RET from one of the centers stated, "The research part of it I think was the best part of it. To take this back to the classroom, also I want the students to experience what I experienced." An RET from another center said the most successful part of their summer research program was the "valuable experiences and skills that will be useful and ultimately transferred to the classroom."

Despite limited accessibility and interaction time with mentors due to the remote format, teachers reported positive and beneficial mentorship experiences. All of the RET participants (100%) reported that their mentors provided high levels of support and displayed professionalism and expertise, helped them establish their research goals, and challenged the RETs to extend their abilities. One of the RET participants said, "The support was fantastic. My mentor always had time for questions and responded quickly to emails." An RET from another center said "A big part of our success was establishing a team and regular check-ins." Another said "My mentor was very helpful and made certain that my needs as a participant were being addressed. [My mentor] was very patient in helping me understand aspects of the project that were not clear to me. I gained a lot of knowledge and experience that will help me be a better teacher."

Lastly, 100% of the teachers reported they would consider applying to another summer research program again and would recommend the program to other teachers. Further, the teachers who had previously participated in an on-site RET program reported the virtual experience to be "about the same" or better than their in-person experience. One teacher stated "The entire program was the most successful aspect. From the orientation to the final presentation, it was and will be beneficial to me and my students going forward."

Use of Common Instruments

Results also suggest that the common instruments were effective in measuring learning outcomes across programs. The instruments were developed to explicitly measure educational outcomes identified by the NSF as standard for RET programs. At the same time, the instruments were developed to be flexible and adaptable, so that they can be used across various content areas and educational programs (e.g., RET, REU, etc.). Moreover, the addition of quantitative and qualitative items related to the virtual/remote context provided a novel opportunity to explore general successes and areas for growth for future virtual or hybrid programs by considering findings across multiple unrelated centers. Although results are representative of three diverse centers, one limitation of this study is the small sample size of each RET cohort. Efforts to expand the use of common evaluation tools across engineering research centers will allow for further development of the instruments as well as a more comprehensive understanding of best practices for ERC programming in both traditional and dynamic contexts.

Benefits and Challenges to a Virtual Format

Taken together, the COVID-19 pandemic-induced remote learning environment had several positive effects on the summer programming. For example, there were several outside speakers that presented to the RETs via VC, exposing them to real-life applications of the engineering field. Another positive aspect of the exclusively virtual learning environment was the increase in accessibility to a wider range of RET applicants. The teachers' proximity of residence and childcare challenges were less of a deterrent from allowing them to participate in the summer research program.

For the centers that hosted participants from various locations within one cohort and combined non-technical synchronous sessions with another RET program, positive feedback was received on the opportunity to collaborate with teachers from various programs due to the virtual environment. Through VC, the teachers were able to present their research and lesson plans to one another. Not only were they exposed to other RET programs and research areas, but they were also able to give and receive feedback on the presentations and give recommendations on ways to improve each other's lesson plans and mechanisms to implement them, both in person and online.

There were also several challenges when hosting the program in a remote learning environment. Although every effort was made to replicate the laboratory component in an online setting, the lack of daily hands-on experiences in the labs was mentioned by participants in all three programs. Also related to the virtual setting was the reduced interaction with project mentors and not being able to troubleshoot or bounce ideas off other teachers as easily. Teachers also mentioned their disappointment in not being able to attend and participate in an in-person NSF Site Visit, however, the RETs found the online nature of the Site Visit and summer programming to have far more benefits to their overall experiences.

Discussion

Shift to Virtual Format

Through the qualitative and quantitative evaluation of the three virtual RET programs, several pedagogical lessons were learned, such as the importance of organization and clear expectations when developing and delivering an online program. Conducting the RET programs remotely provided the teacher participants the opportunity to experience what it was like to be at the 'receiving' end of the instruction, which helped them prepare for remote teaching in the fall. It was helpful to have frequent synchronous meetings to keep everyone on track and provide time for collaboration between the teachers. The virtual format also encouraged more interaction between the teachers and made it possible for those not living near one of the universities to participate. However, participants recommended more opportunities for casual or social exchanges between participants. The use of educational technologies makes it easier to not only demonstrate or teach concepts that are typically done in a face-to-face setting, capturing this content also allows for replicability. Creating lab experiences for research projects that require equipment, materials, and/or other resources for in-person work has the added challenge of recreating these experiences from a distance. If possible, sending materials for an "at-home" set up will provide the teacher the opportunity to contribute to the research remotely. Depending on the research content, it may be more manageable to have a higher mentor/mentee ratio than that of an in-person program. As a best practice in all online settings, regular and constructive feedback throughout the program is essential. To increase interaction and strengthen the relationship between the mentor and mentee, structured and frequent "check-ins" are beneficial. This communication can be done both synchronously through web-based, research team meetings, and asynchronously through a course LMS, cloud-based messaging, or email.

Use of Common Instruments

The creation of common instruments and protocols that can easily be modified and used by various engineering centers enhances the overall education program evaluation. The burden on individual centers and evaluators to develop instruments is reduced, with more time for qualitative evaluation and analysis. In addition, this streamlined evaluation approach provides the opportunity to conduct evaluation research, such as the current study, across multiple education programs in various center settings. Measuring impact across the programs and centers was possible because participants in the three centers were asked the same (or at least similar) survey and interview questions. Based on these findings, the common quantitative assessment survey distributed to RET participants in all three centers at the end of the programs will be revised and new validity evidence will be collected to inform a finalized version. The complementary qualitative interview/focus group questions that address categories that are not as easily assessed using a survey allowed each center to collect supplementary information, based on their special interests, unique setting (e.g. virtual format), or from a specific participant group (e.g. RETs).

Conclusions and Future Work

The use of common instruments and protocols for evaluating across several virtual RET programs was valuable in measuring program impact and informing future planning. Based on the feedback provided by the evaluation, individual centers are able to make programmatic changes in preparation for improving future virtual RET programs. For example, in response to the suggestion to provide clear expectations at the beginning of the program, a virtual mentor workshop will be offered one month prior to the start of the program and the RETs will be provided a document clearly describing program expectations on the first day. To increase collaboration and feedback between the RETs and the mentors, each research group will meet prior to the program and have more structure for feedback and communication throughout. Strategies for translating complex content traditionally delivered in person will be provided to the mentors for effective use in a virtual format.

Providing RET teachers a research experience remotely had the added benefit of reaching those that would otherwise not be able to participate. Typical in person RET programs limit their recruitment to teachers living local to the university. Developing an experience that can be done completely at a distance expands access to teachers unable to attend in person, and in turn, reaches the students of those participating. Although many university campuses are opening back up for in person programming, the three RET programs discussed in this paper will again offer a hybrid/virtual experience for teachers this summer.

The common evaluation instruments used with the three RET programs described in this paper continue to be refined and improved to deliver best practices for evaluating engineering education programs. The next phase of the project is to share the developed instruments with evaluators for other large-scale NSF-funded engineering centers and to standardize their use. Once the common quantitative and qualitative assessments are finalized, a web-based platform will be developed to house all the evaluation instruments and protocols. Guidance for using the platform and each of the tools will be included within the NSF Best Practices Manual and in a developed Evaluators Toolbox.

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