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Lessons Learned in Adopting a Multi-Site Combined REU/RET Program for Exclusive Remote Participation Due to the COVID-19 Pandemic

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Abstract:
The Smart City Research Experience for Undergraduates (REU) and Research Experience for Teachers (RET) (SCR^2) Mega-Site program, which is supported by the National Science Foundation (NSF) (#1849454), was formed in 2018 to address the low participation and graduation rates of post-secondary students belonging to underrepresented minority groups in the engineering field. The participating schools in the program are all minority serving and members of a consortium consisting of 14 Historically Black Colleges and Universities (HBCUs) and 1 Hispanic Serving Institution (HSI), where Morgan State University (MSU) serves as the lead institution. The program targets lower division underperforming REU students who are less likely to have the opportunity to participate in research as undergraduates. Participation in this type of experience has been demonstrated to be transformative and to have the potential to increase retention and graduation rates at these institutions. RET participants are recruited from local community colleges and high schools that serve as feeder schools to the consortium institutions. These teachers are responsible for preparing students who could potentially be interesting in pursuing a college major in engineering by exposing them to hands-on engineering design practices. Over the last two years of the program's existence, 61 students and 24 teachers have successfully participated. As with most 2020 summer programs, the SCR^2 program was challenged by the novel corona virus (COVID-19) pandemic, which hit the United states during the recruitment period of the project. Consequently, the project leadership team decided to offer the summer program remotely (on-line) rather than bring students to the participating three campuses across which the program is distributed. The planning and execution of the program during a global pandemic has brought key insights into techniques, methods, and technologies for effective cross-site communication, faculty advisor/mentor involvement, participant engagement, and leveraging the strong network that connects the participating schools. Essentially, a multi-site remote only combined REU/RET program is efficacious in increasing participant's confidence, knowledge and desire to pursue further engineering research experiences. This paper presents these insights along with supporting program evaluation findings.

Introduction

The National Science Foundation (NSF) provides a significant amount of funding to support undergraduate student research in engineering and science through its Research Experience for Undergraduates (REU) program. The REU program, initially established in 1987, increase access to research opportunities to underrepresented minority students and students coming from non research-focused undergraduate institutions[1]. Research experiences for undergraduate students have long been identified as a powerful tool to support and prepare participants to pursue graduate education in a science, technology, engineering or mathematics (STEM) discipline[2-4]. The earlier students are exposed to STEM research experiences the better their chances of succeeding in STEM related professional careers or in the pursuit of a STEM related graduate degree [5-9]. Undergraduate research serves as an efficient vehicle to motivate students to apply classroom knowledge to real world situations and problems. Research experiences for undergraduates also support the development of specific skills that will be useful to the participants' future research endeavors. This includes that ability to work through the uncertainty and ambiguity present in open-ended research problems[10], gaining a deeper understanding of their discipline[11], development of skills related to experimental and laboratory procedures[12], and developing communication skills and the ability to present technical work to a general audience[13]. Lastly, undergraduate research can increase students' interests in their field of study which can be a key factor to improve undergraduate retention, not to mention the potential for the student to significantly contribute to the faculty's research [14].

Like REU programs, NSF Research Experience for Teachers (RET) programs have existed for many years, and result in numerous documented positive outcomes for the participants[15]. RET programs can help teachers to keep abreast of changes in their fields, help expose their students to cutting edge research, and "bridge the gap" between K-12 classrooms and university research laboratories[16]. Summer research experiences for high school teachers have been shown as an effective means for teachers to develop a better understanding of the skills and processes associated with doing technical research and increase their willingness to incorporate opportunities to do open-ended research in their classrooms upon completion of the research experience[17]. High school science and math courses are increasingly considered as "gatekeeper courses". Essentially, students who excel in these subjects tend to succeed in high school and continue at college in a STEM related degree. However, the inherent rigor of science and math presents great challenges for the educational system. A lack of fully prepared teachers and general teacher shortages are limiting educational attainment of some students, especially those in the under-represented minority group. While the prevalence of technology within the lives of high school students is accelerating, high schools continue to present STEM proficiency in a traditional fashion using outdated and uninspired laboratory instruction. This generally creates a lack of interest in STEM disciplines among these students, which in turn results in low academic achievement and apathy about STEM careers.

The Smart City Research Experience for Undergraduates (REU) and Research Experience for Teachers (RET) (SCR^2) Mega-Site program is unique in that it combines the participation of 14 Historically Black Colleges and Universities (HBCUs) and 1 Hispanic Serving Institution (HSI) to provide quality opportunities in the area of Smart City research, to a large number of underserved undergraduates and the local high school teachers who serve the same communities in which these institutions recruit from for their STEM programs. By combining the REU and RET programs in a synergistic way, undergraduate students and teachers can apply their unique perspective to collaborative engineering problems in a way that enhances their individual experiences. While undergraduate students learn to apply classroom concepts with scientific reasoning to solve real world problems, teachers can leverage their exposure to this process to hone their research skills and develop the required lesson plans and associated activities to enhance their school's science curriculum and laboratories. In turn, teachers can provide feedback to students within their groups from their perspective and experiences as STEM teachers to strengthen reasoning and improve communication.

In early March 2020, during the final recruitment and preparation phase of the program, the COVID-19 pandemic started to accelerate in the united states. As a result, all the host site campuses switched to remote learning and canceled all in-person summer programs. The SCR^2 program was faced with a tough decision to cancel the 2020 summer program or switch to a remote only option as expeditiously as possible. The program leadership considered the demographics of the population the program serves and came to the conclusion that canceling the program may cause additional financial hardships for a significant portion of the participants, as well as squander a valuable opportunity for them to engage in constructive activities over the summer while also providing the program with valuable information about the efficacy of moving to multi-institution remote only combined REU/RET model. Hence, all site Co-PIs agreed to forge ahead with an expedient migration to a remote only option less than two months prior to the start of the program.

Smart City REU/RET Mega-Site Program Background
Research Motivation

The SCR^2 Mega-site is implemented by a 15-member HBCU/HSI consortium consisting of Morgan State, Howard, Hampton, Norfolk State, Maryland Eastern Shore, University of DC, North Carolina A&T, Tennessee State, Florida A&M, University of Texas at El Paso, Alabama A&M, Jackson State, Southern, Prairie View, and Tuskegee Institute. While typical REU or RET sites are located at one university (with the exception of Engineering Research Centers), this program is built around the following research strengths embodied by the consortium institutions: *IoT Security, Renewable Energy, Energy Storage, Smart Grid, Human Computer Interaction, and Advanced Materials*. These particular research topics are well aligned with the overarching research theme of the program, which is Smart and Connected Cities (SCC). The program is organized around five primary host sites (which has been expanded to 6 for 2021), where three were active year, and the students and teachers involved work together in an authentic community. The primary motivation of the program is to recruit and train a diverse population of 30 underrepresented minority (URM) students and 15 teachers who work in minority-serving K-12 schools and community colleges (CCs) on an annual basis. The target students historically have not had the opportunity to participate in research as undergraduates. Participation in this type of experience can be transformative and has the potential to increase their retention and graduation rates. The program recruits heavily from lower lower division students, both from within and without the HBCU/HSI consortium schools, with a focus on students with marginal grade point averages (GPAs) compared to typical REU applicants, specifically students with cumulative GPA between 2.5 and 2.9.

Underrepresented minorities and lower division students have traditionally not been widely represented in engineering REU programs nationwide. Studies have shown that both lower division and upper division students report positive outcomes from undergraduate research experiences at the same rate [18]. Several case studies have shown that one way to improve the retention, graduation and entry into graduate school by URMs is early intervention and exposure to research with strong mentoring for lower division students [19-20]. Summer and year-round research promote student engagement, strong relationships with faculty, and career readiness. Additionally, alumni retrospective reports from those who participated in research experiences indicate higher gains when compared to other graduates in skills such as carrying out research, acquiring information, and speaking effectively [21]. Combining the REU and RET programs increases the effectiveness of each by enabling undergraduate students to apply conceptual knowledge and practice scientific reasoning to solve real world problems while benefiting from the maturity, perspective and experience of high school teachers who aid in applying critical thinking, questioning assumptions and establishing strong communication skills. Similarly, teachers get direct exposure to engineering practice, resources, and hands-on applications that facilitates the inclusion of relevant engineering activities within their lesson plans, which in turn, enhances their school's curriculum.

Methods

Recruitment efforts are coordinated by the lead institution, Morgan State University, in concert with the current active site's principal investigators to recruit and assign the REU/RET participants based on participant preference, evaluation metrics, and recruitment targets. In addition, an effort is made to ensure students have experiences outside their home institution. Prior to the start of the recruitment period, typically in the month of November, each active site develops projects for the upcoming summer, including descriptions of relevant background and skills and pre-projects. Projects ideas are generated by local faculty, sometimes in collaboration with faculty from other consortium partners who conduct research in the same area. Typically, projects are finalized in time for program announcements in December. Ideally, pre-projects are developed for prospective REU/RET participants and offered at the beginning of the calendar year so that students can be better informed and get a head start on their summer research work. Site faculty advisors and graduate mentors develop and deliver the pre-project research and training activities in the months prior to the start of the summer program.

REU participants are asked to rank their choice of host institution based on the research activities offered, faculty involved and location of the site, which dictates the research activities in which they will be engaged. They typically travel to one of the three active host sites and move into the dorms during the first week of June. Since RET participants are coming from local high schools, they do not stay on campus for their 6-week program. During the first week, participants go through an orientation process which includes local research lab tours. There are also introductory/overview seminars and activities on conducting research. Throughout the summer, participants spend 32 hours per week conducting their research, with Fridays dedicated to developing lesson plans (for RET participants) and weekly reports (REU participants) as well as team building activities. Participants present their weekly reports to their colleagues, mentors, and faculty across all the participating institutions.

RET and REU participants are teamed together to work on research projects, where the teachers learn the fundamentals of engineering and research and provide feedback from their perspective and experiences as STEM teachers. This is departure from typical RET programs where guided training is the primary method used to engage teachers. Rather, the SCR^2 program relies on immersive training to provide a stronger connection between engineering research concepts and actual application, which is critical for translation into hands-on activities for high school students. The knowledge and experience of all participants is further enhanced through a weekly lecture series by STEM faculty and researchers across all partner institutions and collaborating industry partners. At the end of the summer, students write a project report while teachers complete their lesson plans and associated activities. The REU/RET teams present their work at a virtual research symposium coordinated by the lead institution. They also create a video 'elevator pitch' on their experience that is made available on the program website. All students are encouraged to continue their research at their home institution. The top 9 students across the whole program are selected to receive stipends during the academic year specifically for this purpose.

High school teachers are often tasked with providing quality education with very few resources to effectively engage students. As such, it is imperative that the teachers are able to provide their students with the needed hardware and components that accompany the activities being developed in the program. At the end of the summer, each host institution works with the RET participants to purchase appropriate hardware and components for them to take back to their classrooms to accompany their engineering activities. Typical smart city-based research activities use fairly low-cost components and tools which makes the research activities very accessible.

Changes Made to Program Due to the COVID-19 Pandemic

Program Recruitment

Once the decision was made not to cancel the SCR^2 program after campuses of all host sites closed due to the pandemic, it was quite clear that fundamental changes were needed for the program to be quickly transformed for remote engagement. Since a large majority of the participants had already been accepted, it was necessary to establish the viability for them to participate in the program in a remote fashion. It was anticipated that some participants may lack access to the necessary computing resources, cameras and a network connection with sufficient bandwidth. Letters were sent out to all participants to inform them of the program change and to confirm their ability to continue with the program in a remote fashion. A resource checklist was provided to ensure a proper readiness assessment could be done. The application process was also amended with this information to ensure the final applicants selected would be aware of the new requirements. Furthermore, participants were informed that the promised stipend amounts would be unchanged for remote participation. Surprisingly, despite the challenges posed by the pandemic, the recruitment targets for the REU program were exceed (31/30). However, the recruitment targets for the RET program did fall short (9/15).

Lab Tours

In 2019, participants received a tour of the research labs at the host institution in which they would be participating. Since that became impossible to do due to the pandemic, faculty advisors were asked to prepare an introductory video of their research activities and the associated labs. These approximately 5-minute videos were presented to all participants during the program orientation. It actually enabled all members of the program, including other faculty, to get a greater appreciation of the research and facilities at host sites. This is a practice that will be adopted going forward even when the program is conducted in-person.

Projects & Supplies

The next challenge to tackle involved transforming existing in-person projects to be conducted remotely. The faculty members associated with each project were tasked to review the project to assess the efficacy of transforming it to be delivered remotely. In part, this decision was based on whether laboratory supplies could be expeditiously obtained online and at reasonable costs, whether alternative more accessible measurement processes could be implemented, and whether design and testing could be done in simulation only. Projects that could not easily be transformed into this mode of delivery were quickly eliminated or merged into other projects. Participants associated with each host site were presented with the modified projects to rank their preference, which were then used to assign project groups. For the projects that required supplies, these supplies were purchased and mailed to their homes. This process proved surprisingly more complex than first expected. Each host site university had their own rules regarding procurement and transfer of materials off-site. For some, it was as simple as obtaining approval from the local purchase card office and purchasing supplies on a university credit card and having them shipped directly to the participants. For others it required generating a purchase order and having supplies shipped to the campus, after which the items had to be repackaged for shipping to each participant. This caused another set of problems since access to the campus was restricted. Essentially, the faculty member had to dedicate a fair amount of time ordering and tracking the packages, coordinating with campus officials to retrieve the packages, repackaging for shipment, obtaining additional funds to ship out products through the aid of the dean's office and finally shipping the materials. Since these challenges are much better appreciated now, this process is beginning much earlier this year as the program is anticipating a hybrid in-person/remote model for 2021.

Mentoring & Community Building

In the SCR^2 program, graduate students are primarily responsible for providing daily guidance and mentoring. In 2019, this was done in person with participants working alongside graduate students within their respective labs. However, with the shift to a remote-only program, the process of mentorship had to be re-examined. It was very important to establish daily contact, as would be the case for the in-person program, in order to ensure participants still feel engaged in the research. Hence, mentors had to establish a daily meeting schedule that was recorded, along with the video conference link, and posted for all program participants. This allowed other group participants, as well as the program coordinators and faculty advisors to join in research meetings periodically. During these meetings, mentors established daily research goals, reviewed progress made over the last day, discuss technical challenges and solutions, as well as ideas from other group participants. Previous work was reviewed and guidance was provided through screen sharing. During this meeting it was required that everyone turn on their cameras to provide a stronger sense of community and engagement. In addition to this required meeting, mentors often engaged in several more meetings within a 24-hour period as the need arose.

It was encouraged to allow all meetings to deviate from research related discussion to any other topics that organically arose. This often-allowed remote participants to get to know each other without the need for artificial team-building constructs. However, the daily (and weekly) goals set by the advisors and mentors served as a guide-post to ensure the necessary research work was still be conducted. These goals help the team prepare their weekly research briefs which was shared with the entire program during the Friday meetings. After the Friday research briefs, participants engaged in remote collaborative lunch session where participants simply ate lunch while being on video conference discussing various topics. Each week, a discussion theme was introduced before the Friday session through the use of a slide deck. Participants were asked to assemble visually oriented slides that presented their perspective on the theme. During the Friday lunch sessions, each participant was asked to present these slides, with the understanding that the conversation could fluidly shift to any other topic as the discussions unfolded. Examples of the discussion themes include: 1) "a movie that changed my perspective on life", 2) "what are you passionate about", and 3) "how the pandemic has changed a fundamental view I have held". The combined technical and social interactions of the mentoring sessions and shared lunches created a support structure that enriched the participant's research and professional development experiences.

Breaking Down Inter-Institution Boundaries

The pandemic offered a unique opportunity to break down inter-institutional boundaries that naturally exist in multi-institutional programs. From the participant project rankings (which were across all host sites), it was clear that some had several interests that spanned institutions. In order for those participants to get the most out of their experience, the ability to "Shadow" one or more projects was introduced. Each participant was assigned a primary project and group, but was also allowed to shadow other projects (and groups) from other host sites. Since all the daily research meeting schedules were selected to minimize overlap, it was indeed possible for participants to participate on multiple projects. Depending on the level of commitment indicated, supplies were sent to students shadowing projects that required them. Given that the workload for the summer would get increasingly untenable if participants were required to adhere to all the responsibilities across multiple projects, the guidance given was to adhere to all the responsibilities of their primary project, and simply participate in the shadow projects in a reasonable way. The effect of this was to expand the experiences that participants had in the program in ways that didn't create undue stress. This process worked well enough that it will be adopted for the hybrid program model going forward.

Research Symposium

The research symposium was always envisioned as a partially remote activity since it involved participants that are not all located in the same institution. However, in 2019 this involved all participants of a host site meeting in a conference room and sharing a video connection to conference rooms in the other host sites. This video conferencing session was also made public to other parties to participate. Groups would pre-record their presentations and present them during the symposium, after which they would take questions in a live format. The benefit of this was to avoid technically issues that may arise and to also create videos of the presentations that are then made available on the programs website.

For 2020, this process was modified slightly.

The elevator pitches were used as an opportunity for participants to build a portfolio of research activities that could easily be shared on social media as well as to provide symposium attendees with a synopsis of research presentations that would be presented prior to the actual presentation. Because the elevator pitches were shared in advance, the audience could post questions/comments prior to the event. The Q&A session that followed the presentation of the research videos was transformed into a discussion session where the teams would more informally discuss aspects of the research that were not captured in the formal presentation and to address any question that were asked in advance.

Projects Summaries

Traffic Video Analytics (Morgan State University)

Participants gain experience in computer vision and machine learning techniques for vision-based traffic analytics such as traffic object localization, traffic object identification/ classification and traffic object counting from vision data (videos). The knowledge is used to build a framework for automating the extraction of relevant meta data for traffic law development, enforcement and improvement.

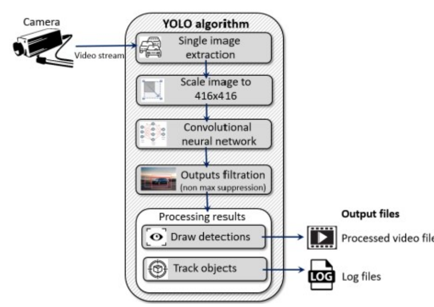

Figure 1. Overview of computer vision process for automated object detection

Infrastructure to Vehicle Communication via Traffic Lights (Morgan State University)
Participants develop a visible light communication (VLC) receiver and transmitter. The transmitter is embedded into a simulated traffic signal, while the receiver is intended to be in a vehicle. With this setup, infrastructure to vehicle communication is enabled where information such as the time remaining for a traffic light to change can be shared with oncoming vehicles. Various modulation methods, such as differential pulse width modulation are explored. Participants develop the transmitter and receiver units using Raspberry Pi or Arduino.

Smart Streetlights with Sound and Motion Detection (Morgan State University)
Participants develop smart streetlights with sound and motion sensors. The purpose of the streetlights is to generate information about gunshots and continuous motion (in case of crime) and send it to the application server. The classification of gunshot sounds is performed on an edge device through machine learning inference. Participants develop various sensing units using Raspberry Pis, in addition to microcontrollers, such as Arduinos. Each unit uses a communication module (Zigbee or Wi-Fi) to communicate with a server to report detected gunshots along with related information such as time and position.

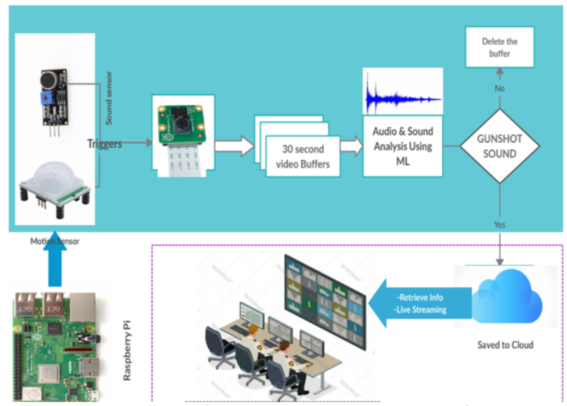

Figure 2. Overview of smart street light system for automated gunshot detection

Medical IOT Testbed (Morgan State University)
The purpose of this research is to develop a testbed comprised of medical Internet of Things (IoT) technologies in order to assess the risks associated with said devices when entered into a home environment as well as to assure security and privacy when it comes to consumers' personal information, data, and other connected devices.

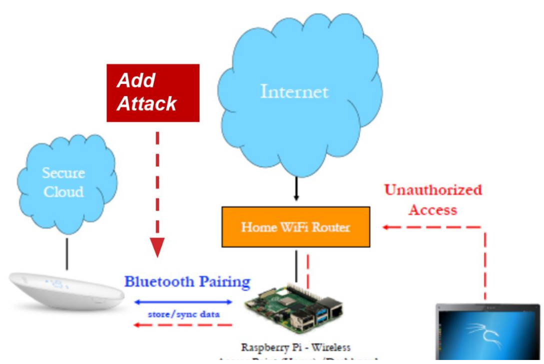

Figure 3. Man in the middle attack scenario with Bluetooth health device

Deploying Edge App using Intel OpenVino Toolkit (Morgan State University)
Participants use Intel OpenVino toolkit to deploy Apps at the edge. Participants apply processing and information extraction on these files by using Computer vision tools (e.g. OpenCV), FFmpeg, and Flask. Inference engines are deployed at edge and MQTT (MQ Telemetry Transport), lightweight publish/subscribe architecture that is designed for resource-constrained devices and low-bandwidth setups are used to stream information extracted from images/videos to a node server. Participants explore MQTT for Internet of Things devices, or other machine-to-machine communication.

Private Certificate Authority (CA) for IoT (Morgan State University)
Participants deploy a Private Certificate Authority (CA) for IoT devices. This project is extended to Amazon Web Services, AWS IoT, where Private CA managed IoT devices can be deployed.

The project enables participants to understand and apply Step-CA to make secure automated certificate management easy, use TLS and easily access anything, running anywhere, from everywhere.

Energy Storage Devices: Characterization and Measurements (Florida A&M University)
Participants learn about the existing electrochemical energy storage devices used in electric vehicles and grid applications, in particular about Li-based batteries, capacitors and supercapacitors. They are also introduced to the existing characterization methods for batteries, such as cycle life, energy and power density and electrochemical impedance spectroscopy (EIS). The project enhances the understanding of the main concepts in sustainable energy systems and the important role storage systems play overall.

Implementation of Distributed Control Algorithms for Multi-Vehicle System (Florida A&M University)
Participants learn about fundamental concepts of control systems and how to implement control algorithms on target devices. They gain experimental skills involving programming and control of a system of unmanned ground vehicles. Participants learn the concept of string stability in cooperative adaptive cruise control of a multi-vehicle platoon. The participants are exposed to programing and simulation in MATLAB/SIMULINK environment, and interact with QUANSER QBots. They perform basic measurements, instrumentation, and data analysis related to control technology.

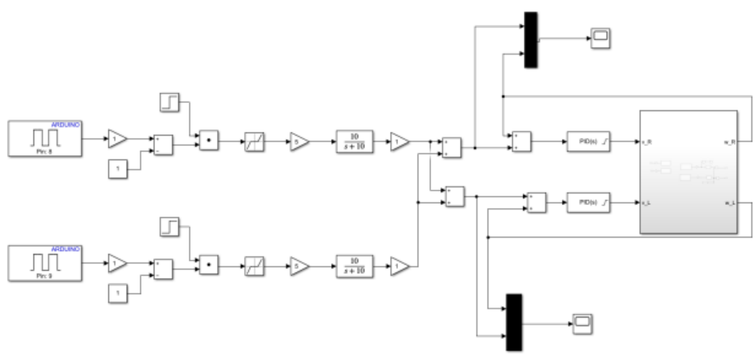

Figure 4. Developed PID controller to stabilize wheel of simulated vehicle

Implementation of Computer Vision Algorithms for Autonomous Vehicular Platforms (Florida A&M University)
This project explores the foundations of artificial intelligence and provide participants with an introduction to the practical implementation of artificial intelligence algorithms used in computer vision and machine learning applications using a do-it-yourself artificial intelligence (AIY) kit.

Fabrication and Characterization of Dye-Sensitized Solar Cells (Florida A&M University)
This project deals with the following concepts in nanotechnology: 1) thin film fabrication, and 2) electron transport in nanocrystals. Participants learn the basic principles of dye sensitized solar cells (DSSCs). Participants have a chance to make a solar cell using simple device fabrication techniques. They also perform electrical measurements of their dye sensitized solar cells and observe how the DSSC performs as a function of light intensity and wavelength.

Simulation of linear circuits and analog circuits (Alabama A&M University)
Participants use NI Multisim software to simulate several fundamental linear circuits and typical analog circuits. The fundamental linear circuits include: Resistive circuits, mesh and node analysis, superposition theorem, Thevenin's Theorem, Operational Amplifier, Diode and Applications, Transient Response, Phase Relations in AC Circuits, and Series Resonance. The typical analog circuits will at least include: Diode analysis, Bipolar Junction Transistor DC analysis, BJT Common Emitter Amplifier, BJT Common Collector Amplifier, Junction Gate FET DC analysis.

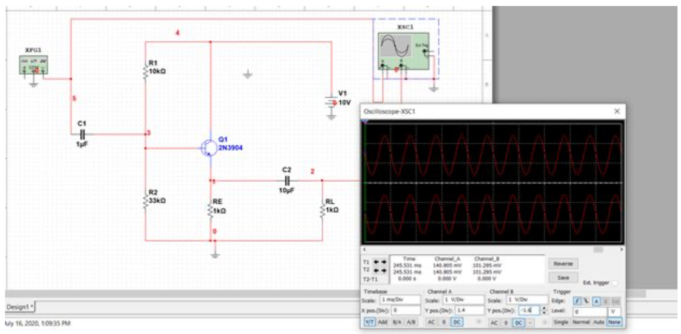

Figure 5. Simulating a BJT circuit

Simulation of Advanced Circuits (Alabama A&M University)
Participants use NI Multisim software to simulate several very important advanced circuits. These circuits include Single Stage BJT Common Emitter Amplifier, Single Stage BJT Common Collector Amplifier, Differential and multistage Amplifiers, Operational Amplifiers, Digital-to-Analog Converters, Analog-to-Digital Converters, BiCMOS Current Source.

Simulation of microwave transmission lines and microwave filters (Alabama A&M University)
Participants simulate two popular microwave transmission lines and two microwave filters. First, participants use two simulation software: AppCAD and Sonnet Lite. They learn the structures of the two transmission lines and the operations of two software. They use AppCAD to simulate both transmission lines and to investigate how the dimension parameters influence the characteristic impedances. They use Sonnet Lite to simulate the microstrip on reflection coefficient and insertion loss. Participants also simulate a microstrip band stop filter and a microstrip bandpass filter using AppCAD, and then simulate both filters using Sonnet Lite software.

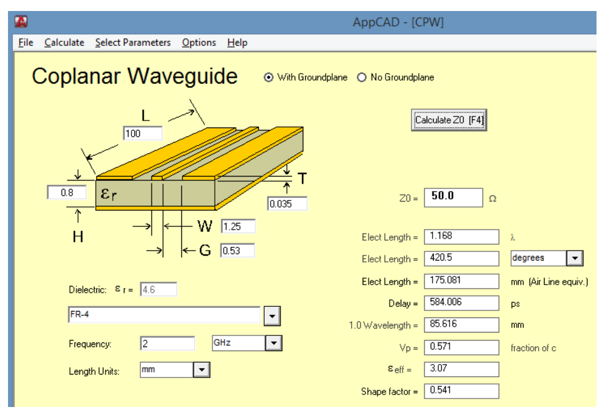

Figure 6. Coplanar waveguide on AppCAD

Insights from 2020 Summer Program

The SageFox Consulting Group is responsible for all SCR^2 program assessments. The insights documented in this section are derived from their assessment report. The assessment instruments used include: A pre-survey for students and teachers; A post-survey for students and teachers; a follow-up survey for students and teachers; and a post-program survey for mentors. These surveys were created in consultation with Audrey Rorrer, author of the CISE REU Evaluation Toolkit survey instruments[22,23], which contains construct subscales measuring research skills, leadership skills, self-efficacy, scientist identity formation, intention to attend graduate school, grit, mentoring relationships, and attitudes about research. The assessment statistics associated with presented insights can is available on the program website [24].

REU Highlights

Surveyed undergraduates overwhelmingly belonged to groups underrepresented in STEM, and those participating in this program showed broad improvements in research skills, academic/career knowledge, and confidence and a consistently high desire to persist in pursuing a graduate degree. The program had differentiated effects for men and women, and for the 2019 vs. 2020 cohorts.

- More students participated in 2020 than 2019, however **fewer women participated.**
- The vast majority of REU participants had **no prior research experience.**
- Students joined the REU to **gain research experience, develop topical knowledge, gain skills, career development and awareness and to develop a network.** This particular REU was appealing as a way to meet these goals and most students were particularly **interested in the topic.**
- The **women entered the REU with less confidence yet greater perceived knowledge than the men**.
- The 2020 cohort was similar to the 2019 cohort in terms of confidence, though the **2019 cohort had greater knowledge and sense of belongingness** than the 2020 cohort at the project start.
- **Women entered with a stronger sense of belonging than men**, a reversal from 2019.
- Students felt **well prepared to work remotely** including adequate technology, time and space.
- The REU leadership team instituted **daily meetings with mentors, the frequency for which 100% of participants report was "just right."** Likewise, the weekly program-wide lunch sessions were successful at **creating a sense of community.**
- Women report greater **gains in confidence** than men, who also had positive gains.
- The 2020 cohort had **greater gains in knowledge concerning presenting research and ethics in research**, yet **lower gains in knowledge related to career options and graduate school awareness and preparing research proposals** as compared to 2019.
- Participants report **increasing their sense of belonging as scientists**, but **not feeling like members of a scientific community**. 2020 participants were **much more likely to report feeling like they belonged in the field of science after the summer experience than 2019** participants did.
- As a result of the program, **women are much more likely to pursue a career in research and advanced degrees in science** than men, who also had positive increases, **particularly at the institution at which they had the REU experience**.
- Despite all the challenges, **the participants report a higher level of satisfaction with the program than the 2019** cohort

Confidence

At the end of the program, students reported a moderate increase in confidence in their research abilities particularly the ability to statistically analyze data. Women in general showed greater gains than men, particularly in their confidence in being able to formulate a research hypothesis. Yet women showed a concerning decrease in their confidence in understanding primary research literature, while men showed an increase. Men showed the greatest increase in their confidence to understand primary research literature and for writing a research paper for publication, while women showed no change in confidence for the latter. Overall, however, the confidence of students in 2020 in engaging in research activities similar to the 2019 cohort. Changes in confidence between the start and end of the program were also similar for 2019 and 2020.

Knowledge

Knowledge about the research process and future graduate school/career options modestly increased, particularly for presenting research, what graduate school is like and ethics in scientific research. The most gains in knowledge were about "defending an argument when asked questions" and "explaining my project to people outside my field." The gains for women were most pronounced in "identifying appropriate research methods and designs," and in developing career awareness including graduate school and research careers. Women also had gains in "understanding theory and concepts guiding a research project: and the nature of the job of a researcher. Men showed the greatest gains in knowledge about presenting research, ethics in scientific research and what graduate school is like. Women showed a decrease in their knowledge about research proposal write-ups and applying to graduate school, perhaps because they now have a more realistic understanding of what is required. The difference in knowledge gained between the start and end of the REU experience for the 2020 cohort and the 2019 cohort were different.

2019 participants had greater growth in:

- Research proposal write ups
- Awareness of what graduate school is like
- Career options in research

While 2020 participants had greater growth in

- Presenting their research
- Ethics in scientific research
- Project management

Belongingness

There was a positive change in participants' sense of belonging in scientific fields. Interestingly, there was no change in their sense of belonging to a community of scientists as a group, though women had modest changes. Women, however, were much less likely to feel that being a scientist is an important part of their self-image between the pre-and post surveys while men were modestly more likely to feel this importance. Women also showed a smaller increase than men in terms of their feeling like they belong in the field of science. In general, the sense of belongingness was lower than in 2019, particularly a feeling of belonging to the community of scientists. It is possible that the remote nature of the program prevented the growth of identity. Somewhat surprisingly, 2020 participants were much more likely to report feeling like they belonged in the field of science after the summer experience than 2019 participants did.

Mentor Relationship

Most (71%) of the students had a graduate student as a mentor in 2020, as compared to about half (50%) the 2019 cohort. Students report a high level of satisfaction with the mentor relationship. The level of satisfaction with mentors was consistent with the 2019 responses, with a few exceptions in which the mentor was rated more highly. This is perhaps an unexpected outcome of the investment in regular communication that was required to work remotely.

Impact on Future

Looking towards the future, participants generally agreed that the program had a positive impact on their ambitions, with some modest differences between men and women. The exception is that women were much more likely to hope their future career will require the use of concepts that were part of the summer research experience. There was, however, slightly less agreement that the area of research was interesting and that the students would like to continue learning about this topic area among the 2020 cohort as compared to the 2019 cohort.

Students credit the program with increasing their interest in the technologies involved in smart or connected cities, and increased their knowledge of the subject. Compared to 2019, students report that participation in the program increased their interest in attending graduate school at the institution where they had the REU experience. Women report a more positive effect of the program than men. At the conclusion of the program, participants were more likely to report interest in pursuing a PhD or an MD/PhD than prior to the program.

Remote REUs

The students were successful despite the transition to a remote REU experience. The challenges related to remote participation were largely related to communication, particularly when working in a team. The management of expectations and relationships when not face-to-face required strong and frequent communications. One student noted that "I was too determined to keep moving and at times was not as great of a team leader as I needed to be. My mentor pulled me aside and communicated her critiques and I was able to become a better team player." Participants also note that maintaining motivation and focus was difficult. Benefits of the remote work included greater flexibility in time management including spending additional time on challenging assignments or being able to take on additional tasks when time allowed.

The REU team worked to ensure that students were well prepared for remote work including having the materials and supplies needed to conduct research and communicate. The REU leadership team instituted daily meetings with mentors, the frequency for which 100% of participants report was "just right." Likewise, the weekly program-wide lunch sessions were successful at creating a sense of community. Students benefited by getting to know each other "outside of the prim and proper professionalism of the update meetings" which facilitated a general exchange of knowledge and a sense of support.

When asked what advice they have for instructors was to maintain frequent and regular communication. This includes clarity around expectations, clear explanation of the research procedures, and setting regular goals. Participants credit clear communication with being important to supporting researchers with staying on track.

Advice for students considering an on-line REU also center around communication, specifically, feel comfortable asking questions and keep team members up-to-date on your progress. Students also noted that time management is important, with several students noting how important it is to get "ahead" of schedule to accommodate the unanticipated, for example errors or more time needed for analysis. The participants also spoke about the professionalism required of the program including producing quality documentation, managing time and expectations, and setting personal goals and deadlines.

Program Satisfaction
Despite all the challenges, the participants report a high level of satisfaction with the program that was better than the 2019 cohort. Women were generally more satisfied than men concerning the faculty advisor. The most rewarding elements of the program reported was learning new skills and the excitement for pursuing careers in engineering. Frustrations were not related to the remote work rather challenges with the software and other research-related issues that are likely to occur in any research setting.

RET Highlights
Key Findings: Surveyed teachers participating in the program report increased confidence and knowledge in research topics and plan to incorporate STEM into their teaching. Gains were slightly more modest than for the 2019 cohort.

- Surveyed teachers saw increases in many areas of confidence, such as writing research papers, understanding literature, and the ethical issues associated with research.
- The 2019 and 2020 cohorts of teachers were extremely similar in their teaching self-efficacy after the program

Teacher Motivation
Most teachers reported that they primarily chose to attend due to their interest in the RET topic. Funding and the ability to do the work remotely were also important. Participants expected a variety of benefits from the program, however all expected benefits were related to bringing research experience and practice to their students.

Confidence
Participants saw increases in many areas of confidence measured, with the largest effects occurring in teacher confidence in areas such as writing research papers for publication, understanding research literature, and understanding the ethical issues associated with research. There was a slight decrease in their confidence to statistically analyze data. Teachers showed minimal differences in confidence between 2019 and 2020.

Teaching STEM
The 2019 and 2020 cohorts of teachers were extremely similar in their teaching self-efficacy after the program. All of the teachers expect to bring lessons learned from their research into the classroom, though fewer report that they will be able to translate what they learned into the classroom than in the 2019 cohort. As a result of the program, teachers report being much more able to improve the understanding of students who are failing and motivating students who show low interest in their work and value learning. Teachers report fewer gains on pedagogical aspects of teaching such as helping students think critically, fostering creativity, and gauging how well students comprehend what is being taught; none of which are necessarily expected to increase as a result of RET participation.

Knowledge
Teachers report an increase in knowledge and interest in the technologies involved in smart and connected cities. These increases were more modest than for the 2019 cohort of teachers. Teachers report that this increased knowledge will have an impact on what and how they teach, particularly as they can offer students more in depth and relevant examples.

Mentor Relationships
Participants had supportive mentors with all teachers reporting their mentor was accessible, approachable and had professional integrity. Overall, the 2020 mentor cohort was viewed more favorably than the 2019 mentor cohort, particularly around the aforementioned attributes, acknowledging contributions, and challenging participants to extend their abilities.

Remote RETs
Teachers report that they were well equipped to participate in the remote RET including technology and physical space and time. Any challenges were individual-specific although there was a general sense of disappointment of not having the hands-on experience that would be available in a lab. Benefits include the flexibility of time. None of the teachers participated in shadow projects, perhaps due to time constraints external to the RET program. Most teachers felt the daily group meetings were just right and that the weekly lunch sessions were helpful in creating a sense of community.

Program Satisfaction
Participating teachers were generally positive in their evaluation of the program with minimal differences when compared to the 2019 cohort.

Mentor Highlights
Seven mentors completed the survey representing 7 students and 3 teachers, thus the survey responses may not be representative, particularly when comparing to last year’s survey responses for which there were 18. The mentors were more positive about the program and the accomplishments of the students than in 2020.

- About half of the mentors returned from last year and **100% would be willing to participate in the future**
- Surveyed mentors **generally had a positive experience with their mentees.**
- The 2020 cohort had **stronger professional and technical skills** than the 2019 cohort
- Mentors report they **are more likely to continue the relationship** with the mentee and work with the mentee **to present research findings at a conference or author a publication than the 2019 cohort.**

Mentorship
Mentors were much more positive than in summer 2019 concerning their enjoyment of the experience, level of support they received and also felt the mentees contributed more meaningfully to their research. This could be because the 2020 mentees had stronger technical and professional skills than the 2019 cohort. When describing valuable skills and any training that might be necessary to help mentees succeed, mentors noted that programming skills would be the most

useful. Mentors report they are highly likely to continue working with their mentee and anticipate moving towards disseminating research results. There is a substantial difference between the response in 2019 and 2020 for the positive, again possibly due to the stronger professional and technical skills of the cohort. Students and teachers, however, are less likely to continue these relationships and research efforts.

Remote Mentorship

Despite the shift to remote instruction, the mentors found it to be a positive experience. Though the projects that required hands-on experience were challenging, they were able to find software solutions. The mentors noted that working remotely meant more learning time and also allowed them to develop new technological skills.

Conclusion

The Smart City Research Experience for Undergraduates and Teachers (SCR^2) is a unique combined REU/RET mega-site involving 14 HBCUs and 1 HSI that provides quality opportunities in the area of Smart City research, to a large number of underserved undergraduates and the local high school teachers who serve the same communities in which these institutions recruit from for their STEM programs. The 2020 program was challenged by the novel Corona Virus (COVID-19) pandemic which hit the United States during the recruitment period. The program team transformed the program to a remote format and provided the necessary technology and mentorship support to ensure its success. The assessments conducted after the summer program showed that: 1) despite the move to a remote offering, the student cohort was larger than in 2019 and continues to be a diverse group in terms of demographics and majors; 2) Students and teachers were well equipped to participate in a remote research experience; 3) participants were satisfied with the program at the end of the summer; 4) students reported gains in confidence, knowledge and belongingness in STEM between the pre- and post- surveys; 5) teachers also report gains in confidence and knowledge and report that the experience will influence how they teach and motivate their students; 6) students, teachers and mentors were all satisfied with the mentor relationship; 7) students report that they increased their desire to obtain an advanced degree; 8) teachers report that they are better prepared to support and motivate their students and will translate what they've learned into the classroom.

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