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The Evolution of Multi-Site Combined REU/RET Program: From In-Person to Virtual to Hybrid

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Abstract

In 2018, the Smart City Research Experience for Undergraduates (REU) and Research Experience for Teachers (RET) (SCR^2) Mega-Site program was launched, aiming to improve the participation and graduation rates of post-secondary students of underrepresented and minority groups in the field of Engineering. Funded by the National Science Foundation (NSF), the SCR^2 program has been successfully conducted for the last three years, engaging a consortium of 14 Historically Black Colleges and Universities (HBCUs) and 1 Hispanic Serving Institution (HSI). Morgan State University in Baltimore, Maryland, is the lead institution for this program. The SCR^2 program is designed to engage underperforming REU students in research opportunities demonstrated to improve students' retention and graduation rates. In addition, teachers from local community colleges and high schools are recruited in this program as RET participants. The experience of RET participants in hands-on engineering research projects helps them encourage their students to pursue engineering as a career. The SCR^2 program offers summer research experience (eight weeks for students and six weeks for teachers) focusing on smart and connected cities. In this paper, we present our learnings from the last three years of the SCR^2 program, which will inform the progress of engineering education and training in the United States. While the 2019 SCR^2 program was able to offer on-campus research experience and mentorship for the REU/RETs, the 2020 program had to go virtual to accommodate the extraneous circumstances posed by the COVID-19 pandemic. Despite this transition, the 2020 program engaged 32 undergraduates and 12 teachers, who successfully participated in 12 research projects across three host sites. Learning from the experience of the summer 2020 virtual program, the 2021 SCR^2 program was redesigned as a hybrid program and was able to bring six host sites together, offering 18 projects in which 47 undergraduates and 23 teachers participated. One major success of the program was the positive impact of remote learning on both students and teachers. Despite the hybrid nature of the program, students excelled in their technical skills due to the effective collaboration using video conferencing tools. However, during the post-program survey, one primary concern was reported regarding the reduced participation of women students in the program. Simultaneously, the women participants reported less satisfaction and reduced confidence and knowledge gain than men. The transition of the SCR^2 program from on-site to online and finally hybrid model exemplifies how innovation in engineering education can overcome the challenges posed by the health crisis. However, it is evident from the assessment results that more attention is needed concerning the experience of women in the program to improve their sense of belongingness in the field of engineering

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Introduction:

Exposing undergraduate students early to research experience is an essential component for enabling them to pursue graduate education in science, technology, engineering, or mathematics (STEM) discipline [1-3]. Early research experience also helps undergraduate students excel later in their careers [4-8]. To support this strategy, the National Science Foundation (NSF) launched the Research Experience for Undergraduate (REU) program [9]. Since its inception in 1987, NSF has continued to provide significant funding for the REU program, particularly to underrepresented minority (URM) students. Experience from the REU program consistently showed that research experience improved students' research and technical capacity and sharpened their communication and leadership skills [10-12], thus leading to higher retention levels in the STEM field [13].

However, the likelihood of students entering a STEM-related undergraduate program largely depends on their exposure to science, technology, and research-related topics during their K-12 school years. Teachers with a better understanding of science and math courses can significantly benefit students to achieve higher academic achievements and prepare themselves for a successful transition into undergraduate studies. However, such support and mentorship are also limited in marginalized communities. To "bridge the gap," NSF introduced the Research Experience for Teachers (RET) program [14]. As part of the RET program, high school teachers get exposure to graduate-level research activities. Upon completing the summer RET program, teachers become much more well-versed in science and technology and demonstrate how to incorporate their understanding into their everyday teaching activities [15].

The Smart City Research Experience for Undergraduates and Research Experience for Teachers (SCR^2) Mega-Site program brings together 14 Historically Black Colleges and Universities (HBCUs) and one Hispanic Serving Institution (HSI) in the field of smart city research. Starting in 2019, the SCR^2 program connected URM students and teachers with the 15 graduate educational institutes to provide STEM-related research experiences. By leveraging the technical expertise and institutional resources, the SCR^2 program was able to combine the strength of both the REU and RET program and made significant strides in improving the research capacity of the undergraduate students and high school teachers [16].

While the 2019 SCR^2 program was able to offer on-campus research experience and mentorship for the REU/RETs, the 2020 program had to go virtual to accommodate the extraneous circumstances posed by the COVID-19 pandemic. Despite this transition, the 2020 program engaged 32 undergraduates and 12 teachers, who successfully participated in 12 research projects across three host sites. Learning from the experience of the summer 2020 virtual program, the 2021 SCR^2 program was redesigned as a hybrid program. This hybrid program was modeled on the successful structure of the remote program from 2020 with both remote and in-person team members, where the in-person team members were those able to participate from the campuses of participating host sites. In addition, some mentors and high school teachers were also able to participate from the campuses of these host sites to engage in hands-on learning with equipment that could not be shipped to remote participants while still involving participation from those remote participants. The 2021 SCR^2 hybrid program was able to bring six host sites together, offering 18 projects for 47 undergraduate students and 23 high school teachers. The transition of the SCR^2 program, from on-site to online and finally hybrid, exemplifies how innovation in engineering education can overcome the challenges posed by the health crisis. This evolution provided an excellent opportunity to understand and document this program's unique opportunities and challenges over the years and the participants' perspectives.

Program Background:

Research Motivation

The SCR^2 Mega-Site program is coordinated by a consortium of 15 HBCU/HSI institutions, including 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. Aligning with the core theme of the program, Smart and Connected City (SCC), this program draws on the specific research strength of the host site consortium members, particularly in the area of Internet of Things Security, Human-Computer Interaction, Energy Storage, Smart Grid, Renewable Energy, and Advanced Materials.

Starting with three REU/RET sites in 2019 and 2020, the program expanded to six host sites in 2021. The SCR2 program aims to recruit 30 URM students and 15 teachers from minority-serving K-12 schools and community colleges each year. However, the 2021 REU/RET program had the largest cohort, consisting of 47 URM students and 23 teachers.

Methods

Morgan State University is the lead institution for the SCR2 program within the consortium. The principal investigator from Morgan State University actively engaged with the individual principal investigator of the other host institutions to organize each year's activity. Each active site (host institutions) is requested to develop a list of projects for the upcoming summer REU/RET program by the faculty members of that institution, which is sometimes performed in collaboration with multiple active sites. This step includes enlisting the project requirements and the necessary skills for the prospective participants. The project conceptualization phase generally starts in November, and by the end of the year, host institutions are expected to announce their projects [16].

As the recruitment of URM students starts, institutions are encouraged to recruit outside of their undergraduate cohort. The program targets explicitly lower-division students from the URM communities within the area of the consortium member institutions. Special attention is given to URM students with grade point averages (GPAs) lower than typical applicants from other REU programs. REU participants are matched to host institutions and specific projects based on their preference, application evaluation metrics, and slots availability. While the program starts in the summer, the participants begin their pre-project engagements at the beginning of the year by working remotely with their host institution's faculty advisor and graduate mentor. Beginning of summer, the REU participants were expected to travel to their host institution, where accommodation is provided for the next 6-weeks. On the other hand, RET participants are recruited from the local K-12 schools and community colleges and thus do not require any accommodations.

During the orientation phase of the program, REU/RET participants go through introductory seminars, project overview sessions, and lab tours. Furthermore, participants are expected to engage 32 hours/week in research and project activities guided by their faculty advisor and graduate mentor during the next six weeks. At the end of each week, Friday, each group of REU participants presents their progress to the entire program and submit a weekly progress report. At the end of the program, REU students are expected to submit a final report and present a video 'elevator pitch' at a virtual symposium organized by the lead institution. The top 9 REU participants across the entire SCR^2 Mega-Site program are encouraged to continue their research after the program by being awarded a research fellowship to support additional research activities guided by local faculty.

At the same time, RET participants are engaged in developing lesson plans on how to integrate STEM topics, fundamentals of engineering, and research into their curriculum. At the end of the summer, host institutions provide additional support to the RET participants by purchasing necessary hardware and logistics to effectively implement the lesson plan they developed during the program [16].

Changes in Method:

Program Recruitment

In 2019, the SCR^2 program was in-person, and the participants were on campus during the entire program. The recruitment was straightforward, and the students had the opportunity to rank the university at which they wanted to participate and the projects they wanted to work on. In 2020, due to the pandemic, the program was moved to a remote modality, and changes were made to accommodate students, teachers, projects, and the pieces of equipment required for each project [16]. Most of the recruitment happened before the pandemic, participants were given a choice to participate in the program remotely, and all of them accepted the changes in participation. The targets for the REU recruitment were exceeded (32/30), but for RET, it decreased (9/15) [16]. For summer 2021, there were few changes in the recruitment as the program was hybrid. The selected participants were offered to either work remotely or in person. Few of the participants opted to be on campus as they were in the same state as the chosen university, and the modified curriculum allowed for such participants to execute both remote and in-person projects due to their proximity to the chosen university campus. The stipend value remained the same irrespective of the choice of the participants to be either remote or in-person.

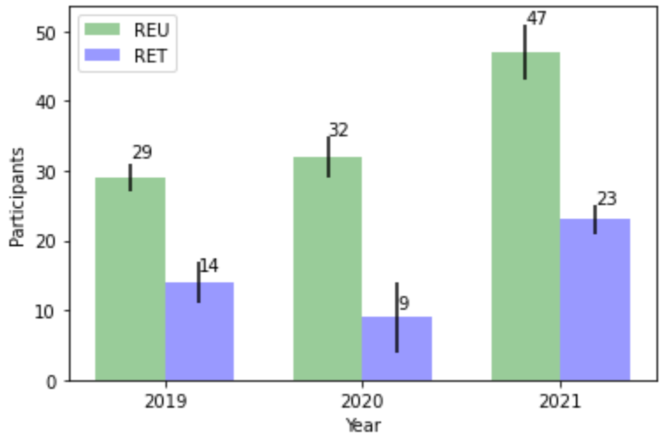


Figure 1. Overview of number of participants from 2019 - 2021

Project and Supplies

The projects of summer 2019 were designed to be in-person, as all the participants were on campus working together in groups. However, due to the pandemic, the projects intended to be in-person had to be redesigned to be conducted remotely or merged with other projects. Due to less accessibility to campuses, the mentors were unable to provide students with data from their labs, which caused few projects to change their expected outcomes. Few participants received their supplies late or damaged, which caused them to purchase these items, for which they were later refunded. For Summer 2021, the priority was to design projects that could be done remotely and required fewer supplies or none. There were few in-person and hybrid projects for the participants who were willing to be on campus. For the hybrid projects, a few participants from the group were on campus while others worked from home, and some mentors collected the data on the testbed in labs and provided it to students to work with. The supplies for the remote projects were ordered earlier and reached the students on time. In case of late delivery of equipment, mentors dropped off extra equipment they had to the participants to make sure students were not behind in their projects. The remote, in-person, or hybrid projects did not affect most of the participants, and they were comfortable working from home and continued working on the projects during the fall semester.

Mentoring and Community Building

Graduate students in the SCR^2 program are mainly responsible for daily coaching and mentoring. In 2019, the participants were in their respective labs, which made mentoring facile. With the transition to a remote-only program, the mentorship process had to be re-examined to create daily interaction, just as it would be for an in-person program, to ensure that participants remained involved in the research.[16] The mentors developed a daily meeting schedule that was documented and publicized for all program participants, and the program directors and faculty advisors attended these meetings to participate in research. Everyone was obliged to turn on their cameras during this meeting to create a better sense of community and engagement [16]. Mentors defined weekly study goals for the participants to design their daily goals and discuss with mentors to ensure they were on the right path. These weekly meetings helped students gain confidence and be responsible for their research. Few mentors frequently held multiple sessions within 24 hours if the need arose, in addition to the mandatory meeting.

Mentors encouraged students to discuss other topics during the meetings, so the participants got to know one another without relying on contrived team-building structures. The adviser's and mentors' weekly (and monthly) goals provided a guide to guarantee that the necessary research work was completed [16]. During Friday meetings, participants presented their weekly work to the entire program. Following the Friday research briefings, participants participated in a remote collaborative lunch session, where they ate lunch while talking about various topics[16]. A PowerPoint deck was used to establish a discussion theme each week, and the participants were instructed to put together appealing presentations that communicated their viewpoint on the subject. Each participant was invited to give these slides during the Friday lunch sessions, understanding that the discourse could shift to any other topic as the talks progressed [16]. The following are some examples of discussion topics: 1) "how pandemic affected their life," 2) "what I have learned about operating effectively in a team," and 3) "What is a profound experience you have had with technology that sparked your curiosity of how it worked or how it could impact people's lives."

Research Symposium

Since the program consisted of multiple institutions, the research symposium was envisioned as an extensive remote activity [16]. All participants from a host site met in a conference room and shared a video connection with conference rooms from other host sites, and the symposium was made public for other parties to attend. To avoid technical issues, the groups were asked to pre-record their presentations and present them during the symposium, followed by a live question and answer session [16]. These videos were then available on the program's website.

In 2020 and 2021, participants used the elevator pitches to develop a portfolio of research activities that could be easily shared on social media and give symposium visitors a description of research presentations presented before the actual presentation. The audience could post questions/comments before the event because of the elevator pitches. Following the presentation of the research videos, the Q&A session was changed to a discussion session in which the teams may more informally discuss parts of the research that were not included in the formal presentation and answer any questions posted in advance [16].

Project Summaries:

Full Remote Projects:

Computer Vision (distance detection between objects) (MSU)

Participants gained experience in computer vision and machine learning techniques for vision-based object detection to detect and estimate the distance of other people within the vicinity of the subject using well-known and proven object detection libraries such as TensorFlow, Keras, Scikit, etc. These libraries were used to build a framework for social distancing compliance and personal security. The extraction of relevant metadata was used to decrease the spread of Covid-19 and enhance personal security through automated monitoring and characterization of a person's surroundings.

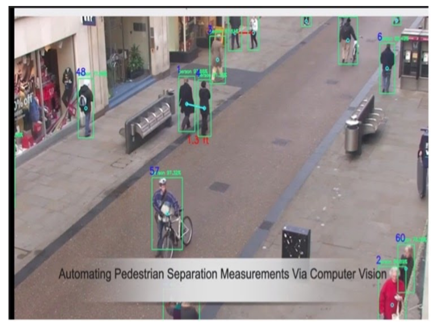


Figure 2. Overview of computer vision distance detection

Smart Crosswalk Light Implementation (MSU)

Participants gained experience in computer vision and machine learning techniques for vision-based traffic analytics such as traffic objects (pedestrian, vehicles, etc.) localization, traffic object identification/classification, and traffic object counting from vision data (videos). The knowledge was used to build a framework for automating the extraction of relevant metadata for traffic law development, enforcement, and improvement. The goal was to implement an automatic smart crosswalk light depending on the automatic extraction of the density of vehicles and pedestrians.

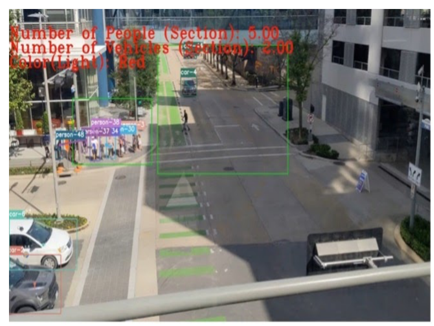


Figure 3. Overview of computer vision Process for smart crosswalk

IoT Application Using Arm Pelion Platform (MSU)

The scope of this work is to give the participants hands-on practice on how to build an Internet of Things (IoT) platform that supports device management, connectivity, and data management. People tend to develop a network of interconnected devices without understanding how the IoT platform operates under the hood. At the end of this project, the participants were able to design an IoT platform and have a clear understanding of its operational mode.

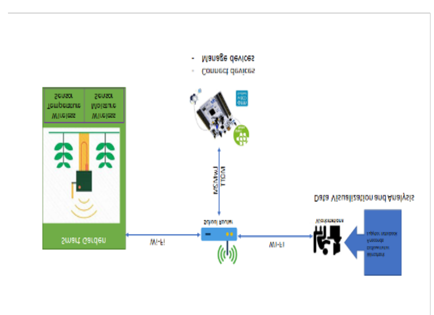


Figure 4. Overview of IoT connected devices

Renewable Energy Collection of Acyclic AC to DC Power: Testing and Verification (PVAMU)

In the first phase of the project, participants learned about environmental issues caused by carbon dioxide emissions and various mitigation strategies. A Thin-film PZT plate was introduced as the energy generating device when subjected to varying pressure. A complete instrumentation system for testing the PZT material was done.   In addition, the participants learned the measurement techniques and testing methodology of an Energy Generating Material (EGM). During the second phase, participants developed circuits that convert acyclic energy from the PZT plate into DC voltage and stored it as usable power. Tests were performed, and data were collected to determine the power generated by the PZT plate.

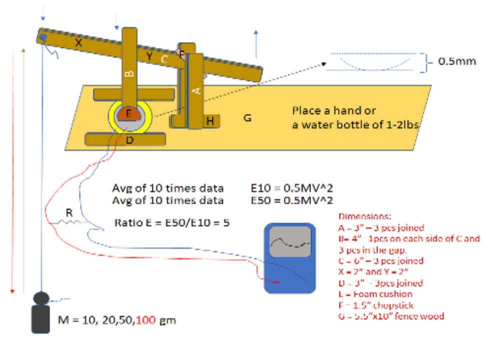


Figure 5. Explanation of collection of data

Estimation of Power Generation by Stressed PZT. Thin Film with Analytical Expression (PVAMU)

The first phase of this project was similar to the previously described project from PVAMU. In addition, the frequency dependence on energy production by the material during applied stress and molecular lattice deformation was discussed. In the project's second phase, signal traces from the EGM were obtained and analyzed to get the energy delivered by the material. Two approaches were used to analyze PZT's average power using the obtained data from the EGM: (1) geometric-mathematical approach (2) development of the general solution for power for the EGM setup.

Energy Storage Devices: characterization and measurements (FAMU)

Participants learned about the existing electrochemical energy storage devices used in electric vehicles and grid applications, particularly Li-based batteries, capacitors, and supercapacitors. They were introduced to current characterization methods for batteries, such as cycle life, energy and power density, and electrochemical impedance spectroscopy (EIS). The project enhanced participants' understanding of the main concepts in sustainable energy systems and the vital role storage systems play overall.

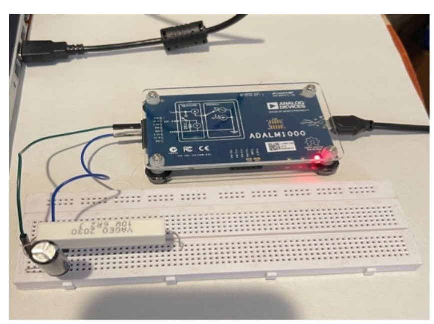


Figure 6. Connection of Energy Storage Device

Smartphone self-diagnosis of Parkinson's Disease (NSU)
Parkinson's disease is a brain disorder that leads to shaking, stiffness, and difficulty walking,

balance, and coordination. The main goal of this project was to develop a smartphone-based easy-to-use self-diagnostic tool to detect the early stages of Parkinson's disease. Android and iOS programming were used to create a user-friendly smartphone app.

Implementation of Distributed Control Algorithms for Multi-Vehicle System (FAMU)

Concerning Cyber-Physical systems, participants gained practical skills involving programming and control of a system of unmanned ground vehicles. They learned the concept of string stability in cooperative adaptive cruise control of a multi-vehicle platoon. The participants were exposed to programming and simulation in MATLAB/SIMULINK environment and interacted with QUANSER QBots!

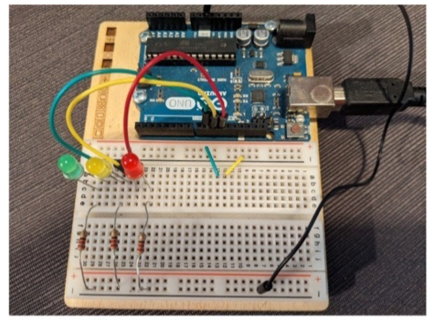


Figure 7. Overview of arduino connection with multi-vehicle system

Embedded Machine Learning (NCAT)

The participants investigated applications of machine learning (ML) that can be implemented successfully with modern inexpensive microcontrollers (such as Arduino), which are characterized by having small amounts of memory (< 1 MB) and low power consumption (can be battery-operated). After being trained in the basics of embedded systems, wearable computing, and deep learning on low-power microcontrollers (TinyML), the participants applied it in researching wearable computing applications, which inherently require low-power and limited memory usage. Finally, participants were required to propose and create TinyML-based learning activities geared toward high school and first-year college students.

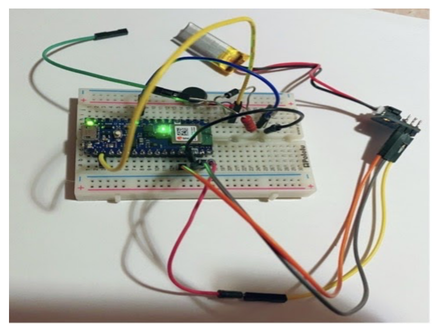
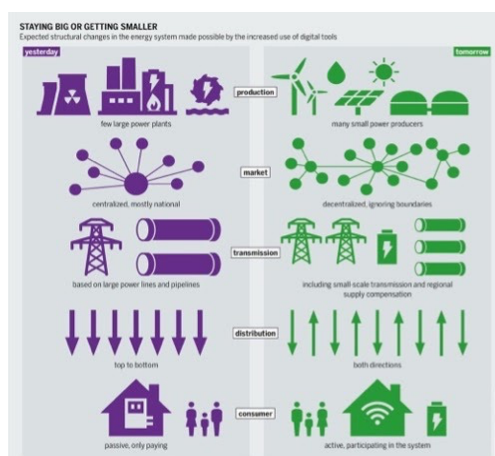


Figure 8. Overview of microcontroller connected to low power battery

Smart Power Distribution Network Simulation Testbed (NCAT)

The participants developed a computer program that simulates a smart power distribution grid with several households; each is equipped with smart heating, ventilation, and air conditioning (HVAC) that adjusts consumption in response to the price signal. Specifically, the participants learned to design and implement a power distribution network in GridLAB-D, an open-source grid modeling software developed by the Pacific Northwest



National Laboratory (PNNL), and TMY, a weather simulation database developed by the National Renewable Energy Laboratory (NREL). The participants customized the referenced IEEE distribution network in the PNNL library by populating the network with household and weather modules. Then, they conducted a simulation on the distribution grid operation under different weather scenarios and demand response price signals.

Hanger Mobile App (NCAT)

Participants gained experience in creating and modifying an application that assists students in finding resources for dealing with the stress imposed by COVID 19. Students will help augment and enhance a mobile application written for Android and iOS mobile devices. Students will also assist in identifying resources for inclusion within the application.

Smart Supply Chain Management (NCAT)

Participants gained experience in decentralized application development for supply chain management. The knowledge was used to build a framework for tracking the time and location of items through the supply chain. Items are uniquely identifiable by Radio-frequency identification (RFID) chips attached to them. An Internet of Things (IoT) device can scan these chips and record this data safely on the blockchain.

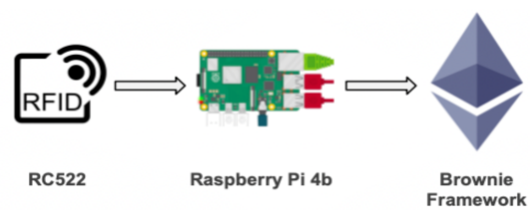


Figure 10. Framework of supply chain management

Full In-person Projects:

Design and simulation of microwave subsystems (AAMU)

Participants simulated two popular microwave transmission lines and bandstop microwave filters. They used two simulation software products: AppCAD and Sonnet Lite, to learn the structures of the two transmission lines. They used AppCAD to simulate transmission lines and investigated how the dimension parameters influenced the characteristic impedances. They used Sonnet Lite to simulate the microstrip's reflection coefficient and insertion loss. They learned the meaning of the simulation results. Then participants designed and simulated microstrip bandstop filters. They used AppCAD to design the filters and then simulate them using Sonnet Lite software. They simulated the filters on reflection coefficient and insertion loss.

Radio Frequency and Microwave Radiation Safety (NSU)

Participants learned about Wireless Transmission Safety Wireless power transfer (WPT). WPT is energy transmission without wires as a physical link. The technology can eliminate the use of wires and batteries, thus increasing the mobility, convenience, and safety of an electronic device for all users.

Hybrid Projects:

Medical IoT - Use Case (MSU)

The motivation for this research is to protect consumers of the Medical Internet of Things (MIoT), also known as the Internet of Medical Things (IoMT). It is desirous to securely integrate these devices into smart home environments. Throughout this research, participants investigated various and heterogenous smart medical devices and communication patterns to understand better the potential threats presented by overlapping medical IoT and smart homes. After the project, participants contributed a capable system platform that allows medical health care providers to monitor patient vitals and provide health-related recommendations and manufacturers to provide secured updates.

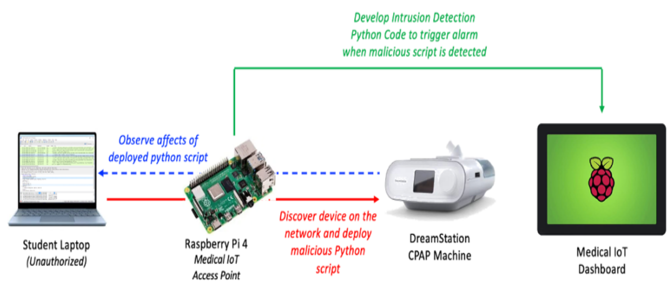


Figure 11. Overview of medical IoT platform

Smart Wheelchair (MSU)

Participants developed a small-scale autonomous platform that served as a stand-in for an autonomous wheelchair developed within the lab. This platform followed a black-and-white guideline along the floor while using QR codes along that line for localization. Sensing was done using a raspberry pi and an attached camera. At the same time, the front-facing ultrasonic sensors provide additional obstacle avoidance.

Figure 12. Smart wheelchair

Magnetic Resonance Coupling Technology (NSU)

The primary goals of this project were to develop a Magnetic Resonant Coupling (MRC) technology for biomedical applications for a more efficient power delivery system. The REU students and RET teachers worked on research projects for developing an MRC system. The participants performed the experiment either virtually or in-person in NSU labs, optimizing the system for either charging a battery or direct power transfer to the medical devices. Students conducted

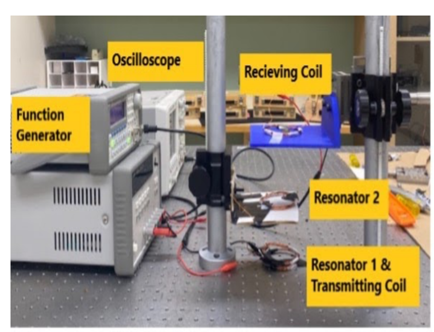


Figure 13. Setup of MRC system in the lab

fundamental studies on electrical and electronic devices and systems for the MRC system. Feasibility study and conceptual design of an MRC system with various parameters such as coil diameter, number of turns, coil radius, inductance, and internal resistances were investigated.

Effective Index of Silicon Nanowires on Silicon Substrates (NSU)

The bare Si surface has a reflectivity of 35% that will be reduced to near zero using SiNW produced by the metal-assisted chemical etching (MACE) process. This property can be investigated using the simulation of an effective refractive index method utilizing MATLAB. Reflectivity data and scanning electron microscopy (SEM) images were made available for MACE-produced samples for the participants to analyze to help control the effective index of SiNW.

Figure 14. MACE setup in the lab

Insights from 2021 Summer program:

The SCR^2 2021 program assessment has been conducted by The SageFox Consulting Group. The assessment was done using a pre-survey, a post-survey, a follow-up survey for REUs and RETs, 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 [17.18]. The surveys contain subscales measuring research skills, leadership skills, self-efficacy, sense of identity as scientists, intention to attend grad school, intention to pursue engineering, mentoring relationships, attitudes about research, etc. This section contains the insights derived from the SageFox assessment report.

REU Highlights:

Despite the hybrid nature of the experience in Summer 2021, the data collected over the last three years suggests that the program has successfully inspired students of color to pursue engineering by offering them hands-on research experiences and mentorship. The survey results of this year showed an increase in confidence, knowledge, sense of identity as a scientist, and intention to pursue engineering as a career. The REU program largely met its goal; however, that data suggests a differentiated experience for women than men this year. The key highlights of the REU program of cohort 2021 have been pointed out below:

- More students participated in 2021 than in 2019 or 2020; however, the percentage of women participating has decreased from 48% in 2019 to 24% in 2021.
- Overall, women were less satisfied with their research experience and the program in general.

- Compared to men, women showed more modest gains in confidence and knowledge.
- Women showed no change in their identity as a scientist, but men did; more concerning, women showed much less likely to feel they belonged in the field of STEM after the REU, while men reported a slight positive change.
- More men reported continuing the REU activities and relationships with mentors after the program than women.

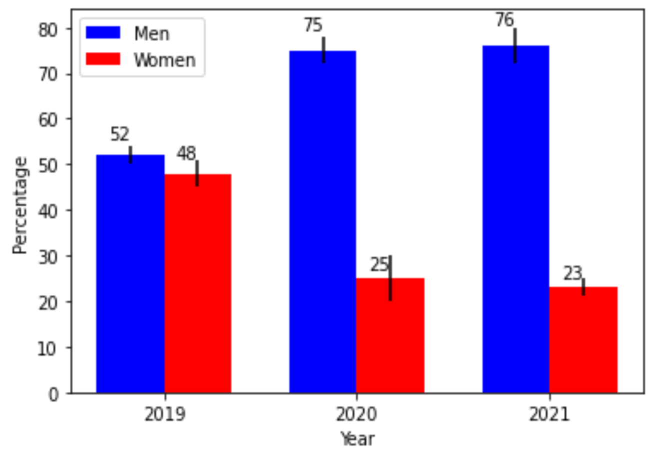


Figure 15. Percentage of men and women in SCR² program over the past three years

Participation

As previously mentioned, more students participated in 2021 than in 2019 or 2020; however, the percentage of women has decreased each year. Almost 85% of students are majoring in electrical or computer engineering. Most students, almost 90%, worked remotely, and students felt prepared to work remotely, including adequate technology, time, and space. Among all, 46% of participants are members of different engineering organizations.

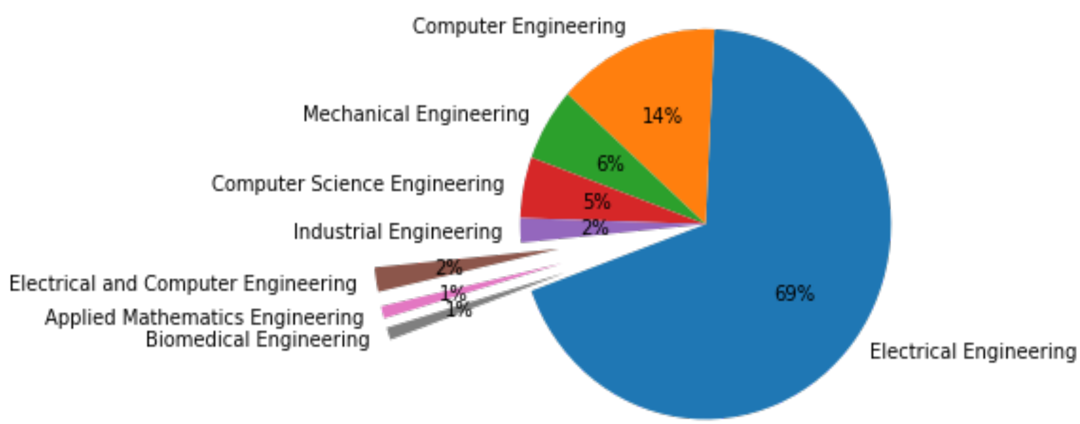


Figure 16. Overview of students majoring in different engineering departments

Confidence

The data shows that participants have increased their confidence in tasks such as working with data and formulating a research hypothesis. Although when asked about different aspects of confidence in several areas such as confidence in collecting data, understanding primary research literature, and locating research resources, women showed less confidence than men.

Knowledge

Through the 2021 REU program, student participants have increased their knowledge and skills, particularly in career and graduate school options. The difference in knowledge gains tended to show men having a more significant increase, but generally, this was by less than half a point. One interesting observation was that students who are not part of professional organizations increased their knowledge around career options and what graduate school is like more than those in professional organizations.

Identity

The survey data showed that women are much less likely to identify themselves as scientists, or they feel less likely to belong in the field of science or STEM. However, men showed much more confidence identifying themselves as scientists after the REU program.

Satisfaction

Students were overall highly satisfied with the program. The 2021 cohort reported the highest level of satisfaction among the three cohorts.

Continued engagement with the research

After the 2021 REU program, many students expect to have a continued relationship with other students and the research advisors. However, when examined by gender, most of these relationships will continue for the men in the program rather than women.

Mentorship

Students are overall pleased with the mentor relationship and support; however, men wear more agreeing to the notion than women.

Remote Work

Despite the hybrid nature of the program, most students had a positive experience. Students requested clear communication, including assignments, due dates, and expectations when working remotely. Similar to other years, time management was critical for students. Working remotely also meant dealing with long hours, which could be fatiguing. Remote learning came with benefits and challenges as the students were able to spend the time needed to learn the material; however, it also led to frustrations for students in fully remote projects, in debugging challenges that may have been resolved quickly face-to-face. Remote work enabled students to connect with others and allowed them to develop a broader network.

RET Highlights:

The 2021 RET experience was overall highly positive for participants. This year the program reached more African-American/black teachers than previous years. The participants enjoyed the flexibility and safety that the remote research experience offered. However, there were minor challenges with the loss of face-to-face introductions, especially with managing schedules. As teachers (RET) started two weeks after the students (REU), RETs had to put more effort into team building. The weekly lunch meetings were an excellent way to improve the camaraderie, connect with other participants, and share ideas for improving classroom management and learning opportunities.

Classroom Impact

Now that everything is virtual, the RET program positively impacted the way teachers approach their classrooms. Teachers greatly valued the opportunity to engage in graduate research, place themselves in the role of students, and explore smart city topics. They reported gaining additional technical skills, the ability to relate to science and math with real-life applications, embracing project-based learning, and greater empathy for students who are struggling with the material. One teacher noted, “the most rewarding experience was when it clicked for me how to integrate what I am learning into my classroom setting. It has encouraged me to continue the development of a project that will unify our school’s science department”. Another comment was, “I was enthused to have an opportunity to learn something new and applicable that I can share with students during the school year.” Another teacher noted, “I will continue to influence minority students to enroll in an engineering program at an HBCU.”

Professional impact

Beyond the classroom impact, several teachers have indicated that they will pursue additional studies through graduate education or future RET programs.

Confidence

Generally, teachers gained confidence in a range of areas except for “confidence writing a research paper,” in which cohort 2021 entered with more confidence but left gaining the least confidence.

Teaching STEM

In their self-assessed teaching skills at the start of RET experience, the 2021 cohort gained more confidence in teaching STEM than cohort 2020. Most RETs were interested in the research topics and learned a lot.

Mentorship

The 2021 RETs reported strong mentorship. They also documented that mentors were approachable, had professional integrity, and were supportive and encouraging.

Potential impact on teaching

All 2021 teachers reported that they would likely bring lessons learned from their research into their classrooms. Many expect to change how they approach science in their classroom because of the research experience in the 2021 summer RET program.

Mentor Highlights:

There were 18 projects this year and 17 mentors in the 2021 REU/RET Program. Among 17, only 12 mentors completed the survey. In comparison to the 2020 program, surveyed mentors were more optimistic about the program and the students' accomplishments. Although surveyed, mentors were less satisfied by the pre-existing technical skills students needed to complete the projects. Mentors generally had positive experiences with their mentees. Mentors reported that they are very likely to continue the relationship with their mentees and work with the mentee to present their research findings at a conference or author a publication. Compared to cohort 2020, mentors of cohort 2021 were much more positive concerning their enjoyment of the experience of mentoring, the level of support they received, and felt the mentees contributed more meaningfully to their research.

Remote Mentorship

Most mentors reported positive experiences with the virtual format of the program, though some noted that they ultimately would have preferred face-to-face interaction due to the nature of their research. Projects based around software development or programming did exceptionally well, as many of them reported that virtual format works best to adapt their research composition. One mentor mentioned that solving license issues for the required software could have made their remote learning experience more enjoyable.

Key Findings from 2021:

One concerning outcome of the 2021 REU program was women's participation and their satisfaction with the program. There were some recommendations from the community to increase women's participation, such as bringing women into the leadership team, bringing more women into mentorship roles, facilitating the connection between women in the program, bringing in women role models, and encouraging membership in professional organizations. However, the 2021 cohort had eight female mentors, the highest number across all three years, and the program also brought women role models to encourage women participation. Nevertheless, the survey result does not show much improvement in women's participation or satisfaction even after facilitating those suggestions. For the upcoming REU program, the survey will focus on to know if the women participants will be returning to the program, what changes can be made for women to participate and their expectations from the program.

One significant outcome of this cohort was how positive the remote learning experience was for students and teachers. One student stated, "It is an amazing chance to network with other individuals in your field, from various cities, states, and countries, that you may not have met otherwise," another stated, "Great to unwind and socialize with people I would have probably never met. Also relieved that everyone has some struggle with their research work and were not alone in the process of research." Another commented, "It was easier to work with coding; understanding and sharing our codes was easier than face to face since we just shared our screens." Teachers also reported that the remote learning experience helped them to bring lessons learned from their research into their classroom.

Few Teachers requested more support ahead of time to better understand the project, and this was particularly salient with coding. Some suggested that a "coding boot camp" may help teachers prepare themselves for STEM research projects.

Conclusion:

In terms of participation, the satisfaction of participants, experiencing STEM research, gaining knowledge and confidence, and identifying oneself as a scientist, the 2021 SCR^2 Mega-Site program was very successful despite the hybrid nature of the program. However, there were few suggestions to improve the quality of the program to reach its goal to the fullest; such as 1) engaging women in a leadership role, mentorship role, facilitating networking between women to ensure women participation, 2) arranging programming boot-camp for students and teachers from non-STEM background or for those who do not meet the prerequisites of the research projects, 3) introducing more hybrid project than fully remote projects (other than software development projects). Implementing these suggestions could ensure major success for future years of the SCR^2 program.

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