Broadening Participation in URE Using PS-MMM-based Mentoring for URM Engineering Students

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Broadening Participation in URE Using PS-MMM-based Mentoring for URM Engineering Students

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Abstract

This work highlights the positive impacts of a Ph.D. Student-Mediated Mentoring Model (PS-MMM)-based program that targets underrepresented minority (URM) engineering students. In particular, a case study of one of the mentoring projects is described which shows how a research project in emerging disruptive technology, namely blockchain, can be used as a vehicle to build a sense of belonging and improved professional development skills in URM engineering students. After identifying effective Ph.D. mentors on high-quality research projects, a vetting process that seeks out undergraduate students who have expressed an interest in research and demonstrated an aptitude for supplemental learning is used to select undergraduate mentees. The research focus of the mentor is matched with undergraduate URM mentees' research interest to form a mentoring group. Throughout this experience, students were given weekly research plans to perform literature reviews on their research topic. There were pre- and post-surveys incorporated to measure participants' metacognition to simulate the highest possible learning quality. The results of this work show that 94% of participants gained a sense of belonging while participating in the program during the spring 2022 semester. Even though lack of interest and motivation to finish the research project is one of the main challenges in Undergraduate Research Experience (URE) design, 100% of mentoring groups (10 out of 10) have successfully continued with their research project and submitted a technical poster describing their research results. Also, 80% of participants prerecorded their presentations and participated in the live research showcase. This work contributes to developing the best practice model for broadening participation in research using a PS-MMM for URM engineering students in emerging technologies. In some cases, highly qualified underrepresented high-school students are identified and added to the team as engineering apprentices allowing them to design procedures and disseminate findings under the direction of their Ph.D. mentor.

Literature Review

Engineers enable technological innovations that have the potential to improve lives and revolutionize industries. Electrical and computer engineering careers provide excellent opportunities to make a difference by designing, developing, testing, and directing production operations for cutting-edge systems and equipment. According to the U.S. Bureau of Labor Statistics (BLS), as of 2016, there is a 7% increase in jobs for electrical and electronics engineers through 2026 (The University of Utah, 2020). However, low enrollment and high attrition rates in Science, Technology, Engineering, and Mathematics (STEM) education are major challenges in higher education (Sithole et al., 2017). More specifically, the enrollment and graduation rates for the Electrical and Computer engineering graduate programs (Full-Time enrollment) have decreased by 50% over the past 10 years (Joseph, 2018). Concurrently, research on strategies to increase inclusion/diversity in higher education pipelines has shown that only 20% of the students enrolled in higher education programs are US residents (Wingfield, 2017). Furthermore, almost half of the generation Z students (48%) are associated with racial/ethnic minority groups (Cilluffo & Cohn, 2019). Due to the rapid enhancement of technology and the growth of STEM occupations, there has been a 79% increase in STEM employment. While there has been significant progress for diversity and inclusion, African American workers continue to be underrepresented in the STEM workforce. Based on the 2016 BLS, only 11.7% of the employed population were African American workers of which only 8.6% of them were professionals in computer and mathematical occupations. Regardless of the increasing diversity in the next generation of the workforce, URM students frequently face a lack of educational opportunities, stereotype threats, and career planning as well as challenges that many STEM students face regardless of their race or ethnicity (e.g., limited student-faculty interactions, high sense of competition). Based on the latest "Science and Engineering Indicators" from the National Science Foundation racial and gender disparities are persistent in the total number of students who successfully finish a graduate STEM degree (Carter et al., 2019). Research revealed that URM students experience a negatively impacted STEM disciplinary culture in PWIs due to stereotypes about lower proficiency in math and science and undervaluing them with a lower expectation of their presence among geniuses (Carter et al., 2019). Furthermore, a survey carried out among women working in technology by (Botella et al., 2019) has revealed that 48% of the women in technology were lacking mentors during their professional careers. Despite a wealth of best practices published over the past 20 years and significant investments in broadening participation in URE, the low presence of URM students in STEM and lower interest/intentions in pursuing a graduate degree remains a reality (Sithole et al., 2017). There are various factors related to racial and gender diversity problems such as socioeconomic and socio-emotional inequalities for URM students at different academic life stages from kindergarten to college. Therefore, the focus of this research is to identify the best approach to developing curricular and hands-on activities that would increase URM students' engagement and promote their professional careers.

Several authors have worked on identifying the barriers faced by URMs and the best approaches to build STEM pathways for increased engagement and successful graduation of URMs (CANNADY et al., 2014; Frederick et al., 2021; McGee & Bentley, 2017; Washington & Mondisa, 2021; Zanetell & Schusler, 2022). Among the identified solutions in the previous work, URE has been proven to be one of the most effective methods to boost Grade Point Averages (GPAs), STEM engagement, and graduate-level STEM program enrollments for undergraduate students (Lancaster & Xu, 2017). Faculty-mentored undergraduate research is one of the high-impact practices that can enrich URM student experiences and success (Pierszalowski et al., 2021). More specifically, Hunter et al. *(*2007*)* presented that the apprentice-style research experience, in which students work with a faculty mentor closely to conduct outside-the-classroom research helps URM students to learn/work like scientists and gain a better understanding of the nature of scientific knowledge. In addition, peer mentoring has been one of the solutions to the academic challenges faced by students in STEM. Peer mentoring provides a sense of belonging to a larger community that can help students to adapt to new academic environments in stressful situations (Sithole et al., 2017b). After the Covid-19 pandemic, access to undergraduate research was fundamentally altered and shifted towards remote platforms. Examining the impacts of these changes on students' academic engagement, retention graduation, and undergraduate research training has revealed that many engineering students lacked the mentoring support needed to conduct engineering research (Grineski et al., 2022; Morales et al., 2022; Speer et al., 2021). Results from the adaptation and remote delivery of undergraduate research training during the Covid-19 pandemic demonstrated that having access to a graduate mentor has helped URM students to build knowledge, make progress in research and be successful in their program (Erickson et al., 2022; Yowler et al., 2021).

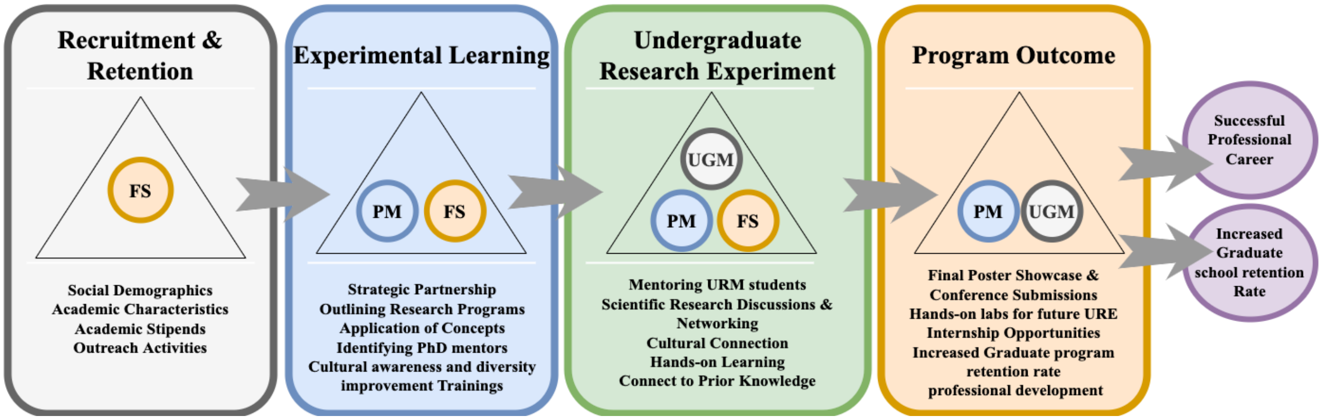
PS-MMM is a newer approach to diverge from the traditional faculty-mentored undergraduate research. In this model, undergraduate students are mentored by Ph.D. students under the supervision of a faculty advisor. Such an approach has been proven to not only broaden the research experiences available to undergraduate students and improve their learning (McDaniel et al., 2022) but also facilitate the Ph.D. mentors' journey to acquire the necessary knowledge, skills, and experiences for success (Singe et al., 2021). Educational acceleration is an important class of interventions that comprise the appropriate educational dose for individuals. Technology is now a core strategic foundation for academia and can be a key determinant of organizational success. Addressing barriers to URM participation in engineering requires changing the system that holds the current policies and practices in place. Research has shown that an evidence-based acceleration strategy is way more effective to support student achievement than traditional remediation strategies. This research is thus designed to catalyze changes that will leverage emerging disruptive technologies, namely blockchain, as a vehicle to develop a mentoring model for its URM participants to benefit from accelerative learning opportunities. Our PS-MMM training landscape leverages the effectiveness of both URE and peer mentoring to broaden the success and graduate program retention rates in engineering. This work by collaborating with national government laboratories has built the capacity to broaden the participation of individuals from groups that have been historically underrepresented and underserved in STEM and cross-disciplinary experiential learning. The next section will provide further details on the strategies, design, and implementation of our PS-MMM along with the evaluation and assessment results.

Design Methods

This study implements a PS-MMM while supporting the case-based learning style of active learning pedagogies. By performing an empirical analysis of students' level of interest in the ongoing technologies and collaboration of faculties in the department who are working on different research areas, we have defined 10 research projects in the Spring 2022 and 22 projects during the Summer 2022 semesters. The general overview of our approach is demonstrated in Figure 1.

Figure 1

Overall Approach and Design Methods



A vetting process that seeks out undergraduate students who have expressed an interest in research mentoring and demonstrated an aptitude for supplemental learning was used to select undergraduate mentees. We have started our recruitment by sending an invitation to all URM students within the Department of Electrical and Computer Engineering to attend a virtual orientation session in which resources and opportunities for them to engage in undergraduate research were discussed. After attending the orientation session students were asked to fill out an E-form on their demographics and their level of interest in joining the available research projects. We have further identified Ph.D. students who could serve as effective mentors on high-quality research projects. The research focus of the mentor was then matched with URM student research interests to form a mentoring group. The research projects were outlined by faculty supervisors, directed by Ph.D. student mentors, and implemented by undergraduate researchers.

The case-based learning style of active learning pedagogies has been proven to be the most constructive teaching approach (Hood Cattaneo, 2017). The case-based learning style involves (1) Exploring, (2) Diagnosing, (3) Problem Solving, and (4) Repeating to reach understanding (Hood Cattaneo, 2017). Following the same concept, students were (1) introduced to their research topic and related concepts, then (2) presented with a real-life problem along with the diagnosis of how their research topic was aiming to solve it (3) asked to identify potential solutions through reading scholarly papers, and finally (4) asked to repeat the same procedure on another real-life problem so that they would adapt their previous experience and knowledge to work their way through the new situation. Given the fact that recent trends in electrical and computer engineering are towards computer systems, electrical circuits, and applied physics (Randy Berry, 2022), we have offered research projects on 3D printing, additive manufacturing, parallel computing, characterizing additively manufactures electrical insulation samples, electrical properties of grey pro- resin doped with Nanopowder and blockchain, which will be further discussed as a case study in this paper. Moreover, weekly research group discussions and monthly group meetings with faculty were held to engage UREs in critical thinking. Furthermore, there were pre-and post-assessment surveys designed to analyze the effectiveness of our methods as well as collect any suggestions for improving the research programs in future offerings. The participation of all groups in the final showcase session, along with the activities and deliverables of all groups, and the implementation of research conduction methods, were documented. In summer programs, a highly qualified underrepresented high-school student was also identified and added to the team as an engineering research apprentice. Collaborating on a project and sharing responsibilities among the research group offers efficient use of resources and benefits all stakeholders.

Case Study

This section describes a case study of one of the mentoring projects to demonstrate how a research project in emerging disruptive technology, namely blockchain, can be used as a vehicle to build a sense of belonging and improve professional development skills in URM engineering students. With the emergence of blockchain and the ever-increasing demand for blockchain professionals and developers, many UREs have shown interest in learning about it and its real-life applications in engineering. We have formed a URE group for this project and trained them on blockchain and related concepts such as cryptography and encryption. Students were then presented with deepfakes as a current societal challenge. They were then introduced to decentralized applications (Dapps) as a potential solution to the diagnosed problem. Finally, with the guidance of their Ph.D. mentor, students were instructed to propose and design a blockchain-based solution to combat deepfakes. This project implemented a media sharing Dapp (web application) that provides a trusted distribution channel with improved traceability and transparency to avoid the spread of misinformation/deepfakes. The implemented solution resulted in a Dapp framework, that is Deployed on Polygon's Test Network (Mumbai) which connects with Ethereum's Goërli Testnet demonstrated. This has trained students on Web3 concepts and introduced Ethereum as an open-source blockchain to combat the security challenges of over-centralization of the web. The coding environment was set up with the help of Truffle and the Smart Contracts were written in solidity. The front-end of the DApp was implemented in react-native to be cross-platform and the Inter Planetary File System (IPFS) was used to store the hashes of the uploaded media to the blockchain. Cross-functional collaboration has been practiced in all research projects. URM students in this project were assigned to tasks associated with individual components and elements of the framework while collaborating to maintain a working framework at all times on a shared repository. This promotes diversified perspectives, encourages transparency, and increases engagement. This project included the integration of all the aspects of blockchain, along with its application to help students systematically learn and comprehend fundamental concepts. Utilizing this research topic allowed us to arm URM engineering students with the required information to manage their professional careers as well as encourage teamwork.

Results & Discussion

A total of 25 students have registered to participate in the Spring 2022 research mentoring program, 52% of which were were Computer Engineering majors, 36% in Electrical Engineering, and the remaining 12% in Computer Science. The program offered 10 research projects involving 8 graduate mentors. Table 1 provides the demographics of the URM students who have participated in our spring 2022 URM PS-MMM. Please note that even though the program is specifically designed to increase URM engineering students' engagement in URE, the program was open for anyone from any background and ethnicity to join too. Therefore, 8% of the participants were Asians who are not traditionally considered to be URM in STEM fields given they are overrepresented.

Table 1

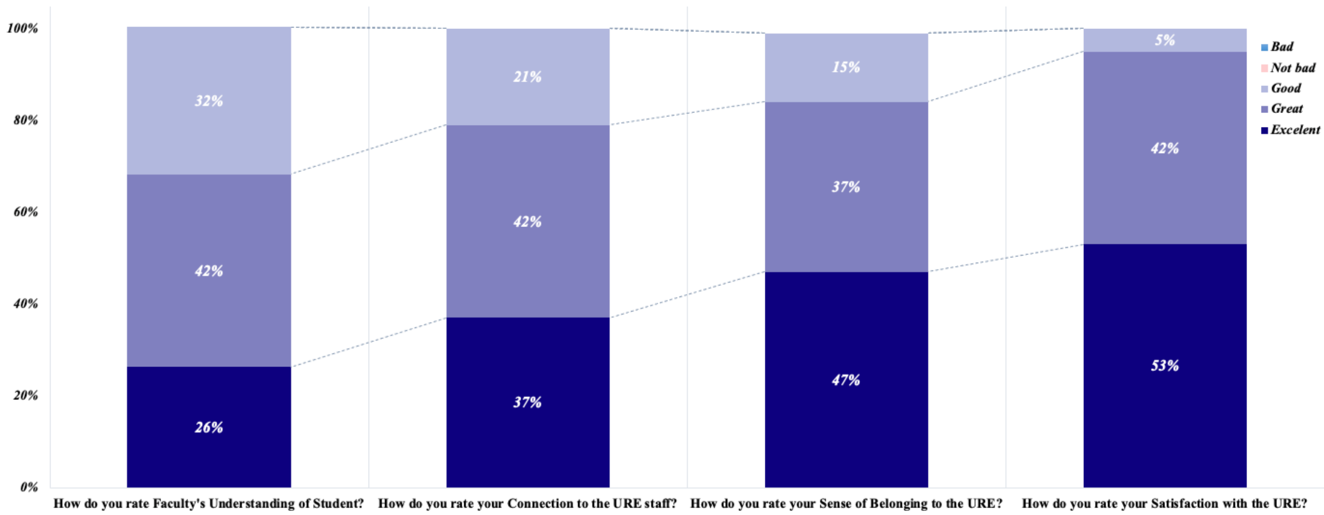
Demographics of URM Student Participants

Race/Ethnicity			First generation College Student	Classification			GPA		Previous Research Experience	Financial Support
Black or African American	Asian	Latino		Sophomore	Junior	Senior	>3	<3		
88%	8%	4%	40%	8%	44%	48%	44%	56%	24%	32%

An improvement means having a change from one condition (before) to a better condition (after). So, to assess students' improvement, we have used a pre-measure (before participating in the PS-MMM-based program) and a post-measure (after participating in the PS-MMM-based program). The pre-survey asked students to report their research areas of interest, skills they would like to obtain after completing the program, their sense of belonging to the people, faculty, and staff of the department, and their level of interest in REU. The post-survey was designed to ask students to reflect on the impacts of the REU, their level of expertise and the skills they have obtained after completing the program, and how it has influenced their future goals. Students were prompted to think back on their experiences and consider whether the PS-MMM helped them rate their professional progress more favorably. Short-answer and multiple-choice survey questions allowed for the collection of both quantitative and qualitative data. Mentors generally had favorable opinions of the mentoring relationship, communication, and productivity. Even though according to URM mentee comments, many of them believed that their interactions with their mentors had improved their interest in STEM, there were also a few students who lost interest in their project or had conflicting demands on their time due to their course load. Therefore, it is critical for everyone involved to be aware of and willing to dedicate the time and necessary resources for the completion of the project. Explicitly splitting mentoring roles and having clear expectations regarding the time and format the mentee and mentors should contact can reduce the risk of students taking on too many responsibilities and thus not allocating the required amount of time to the REU. Furthermore, communication and organization of meetings are more challenging among a larger group of people compared to the traditional faculty mentoring programs. Considering that the research groups include students with a different set of skills and engagement levels, it is important to set an efficient communication channel for mentees to get help and feedback. Meeting cadence, as a measure of duration and frequency of the meetings, plays an important role in student engagement and research interest. Figure 2 demonstrates the post-survey responses. The PS-MMM results show that 94% of participants gained a sense of belonging to their research group by having weekly meetings with their mentors. Overall, 86% of the students indicated that their mentor has provided honest feedback which helped them to advance in their future careers. Even though lack of interest and motivation to finish the research project is one of the main challenges in URE design, 100% of mentoring groups (10 out of 10) have successfully continued with their research project and submitted a technical poster describing their research results. Also, 80% of participants prerecorded their presentations and participated in the live research showcase. Furthermore, 95% of the students were satisfied with their choice of being involved in REU and believed that it facilitated their career development as an engineering student. Additionally, 89% of the students were having an improved sense of belonging to the department and faculty and a feeling of respect after they participated in the program, and 84% of them found the program welcoming.

Figure 2

Post Survey Results (Student Feedback)



Conclusion

This PS-MMM has offered a wide variety of research opportunities for URM engineering undergraduate students. Through workshop and career advising sessions, we were able to increase URM students' engagement in research. Having access to research mentoring experience and hearing about the progress of other research groups in monthly meetings with faculty may encourage innovation in research methodology. Furthermore, presenting the research progress and the rationale behind their choices for a larger group at the final poster session and showcase can facilitate knowledge preservation. Our model addresses pressing challenges facing the discipline of ECE, especially the shortage of URE available to URM students and the wide research–practice gap. Under this methodology, URM students have a deeper comprehension of the issues and sensible solutions directing the change in the engineering landscape. Our proposed model aimed to broaden participation in engineering and invested in increasing diversity in the engineering workforce. We have seen consistent, beneficial outcomes for mentees and mentors under our PS-MMM, despite heterogeneity in the specifics of individual mentoring interactions. Our PS-MMM demonstrates the importance and positive long-term educational-occupational impact of educational acceleration among URM engineering students. Future work can invest in adapting this PS-MMM to other STEM majors. Further research can be done to examine the long-term benefits (graduate programs retention rate, professional career improvements) of the PS-MMM for both mentees and mentors. Additionally, investigating all individual components of the mentoring relationship to prioritize key features can be leveraged to optimize the designed model.

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