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Expanding Access to Research Through an NSF REM in Microelectronics for Undergraduates and Educators

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NSF INCLUDES: Expanding Access to Research Through a Research Experience and Mentoring Program in Microelectronics for Undergraduates and Educators

Introduction

The United States faces a growing demand for a skilled microelectronics workforce [1]. Meeting this demand requires intentional efforts to prepare students and educators through early exposure to hands-on research experiences and broadened participation in STEM research. However, many students and educators lack access to high-impact research opportunities known to support long-term success in STEM fields [2], [3]. Community college students are one such group with limited opportunities to participate in research, gain hands-on experience in cutting-edge research lab facilities, or receive mentorship and sustained support from scientists and graduate students. Although many students enroll in community colleges for vocational training, a substantial number intend to transfer to four-year institutions to complete bachelor's degrees [4], [5]. Students pursuing STEM transfer pathways are especially important within national efforts to diversify and expand participation in the STEM workforce [6]. Yet these students frequently encounter structural barriers to engaging in research-intensive experiences that are more commonly available at research universities.

Similarly, high school educators face limited access to current research environments. Without exposure to contemporary laboratory practices and emerging technologies, teachers may have fewer opportunities to integrate authentic, research-based experiences into their classrooms. Increasing educators' engagement in active research has the potential to strengthen classroom instruction, improve student engagement, and enhance awareness of STEM career pathways.

To address these gaps, Rice University hosted a Research Experience and Mentoring (REM) program for Undergraduates and Educators, funded by the National Science Foundation's (NSF) INCLUDES Initiative, and served as a supplement to a Research Experiences for Undergraduates (REU) Site in the Division of Engineering Education and Centers. This supplemental program was designed to expand access to mentored research experiences for community college students, four-year undergraduates, and STEM educators.

Literature Review

National Microelectronics Workforce Need

The United States is facing an urgent need for a highly skilled microelectronics and semiconductor workforce. According to the U.S. Department of Commerce [7], semiconductor and electronics companies invested approximately $450 billion in domestic manufacturing and supply chain expansion between 2021 and 2024. In addition, an analysis by McKinsey & Company [8] projects that the U.S. semiconductor market could nearly double in value to $140 billion by 2030. These projections highlight the importance of developing a robust and sustainable talent pipeline. Meeting this demand requires coordinated efforts across educational levels, including community colleges, four-year universities, and K–12 systems. Preparing students for careers in microelectronics involves early exposure to authentic research environments, interdisciplinary collaboration, and structured professional development opportunities. Expanding access to these experiences is essential to strengthening workforce readiness and broadening participation in high-demand technical fields.

Undergraduate Research

Undergraduate research is widely recognized as a high-impact educational practice that promotes student engagement, persistence, and academic success. In STEM disciplines, persistence is strongly influenced by access to experiential learning opportunities such as undergraduate research [2], professional mentoring [3], and exposure to graduate education pathways [9]. However community college students often face structural barriers to participating in research-intensive experiences. While substantial literature documents the benefits of undergraduate research for students at four-year institutions, fewer studies examine cross-institutional models that intentionally integrate community college students with university undergraduates in shared research environments. Expanding research access through collaborative, multi-institutional models may help address equity gaps and strengthen STEM transfer pathways.

Research Experiences for Teachers

Research Experiences for Teachers (RET) programs were established by the National Science Foundation to strengthen K–12 STEM education by immersing teachers in authentic research environments and supporting the development of research-aligned instructional materials. Existing literature documents numerous positive outcomes associated with RET participation, including increased content knowledge, improved understanding of scientific and engineering practices, and greater familiarity with inquiry-based instructional approaches [11]. Teachers who complete RET programs frequently report increased confidence in implementing innovative instructional strategies and stronger alignment between classroom lessons and real-world STEM applications [12]. These outcomes are particularly significant in engineering education, where translating complex research concepts into developmentally appropriate classroom activities remains an ongoing challenge [13].

Program Design

The REM program offered a diverse cohort of 2 high school STEM educators, 4 Houston-area community college students, and 5 undergraduate students from Rice University the opportunity to participate in mentored, microelectronics-focused research projects. Over six weeks, participants engaged in an immersive research and mentoring experience focused on applied microelectronics. Through engagement in research under the guidance of graduate student mentors, participants expanded their knowledge of microelectronics while developing critical thinking, problem-solving skills, and a deeper understanding of high-need microelectronic technologies and semiconductor industry concepts. The mentorship model utilized in the REM program was based on the *Entering Mentoring* [14] and *Entering Research* [15] curricula, which not only allowed participants to strengthen their technical knowledge but also supported graduate mentors' professional development through formal mentor training and opportunities.

Methodology

Research Design

This study employed a mixed-methods program evaluation design to examine the impact of participation in the REM program. The evaluation focused on four primary outcomes: (1) Increasing participant knowledge and professional development skills in microelectronics, (2) developing and fostering best practices regarding the cleanroom, (3) improvement of mentoring practices, (4) increasing awareness of job opportunities in microelectronics. As such the overarching research question guiding this program evaluation was: **To what extent did participation in the REM program influence participants' research knowledge, professional skills, mentoring experiences, cleanroom practices, and awareness of career opportunities in microelectronics?**

Data Collection and Analysis

Eleven participants completed post-program surveys assessing research skills, professional development skills, mentoring experiences, laboratory and cleanroom practices, and career awareness at the end of the six-week experience. Survey items used Likert-scale response formats. Quantitative survey data were analyzed using descriptive statistics to summarize participant responses. Individual interviews were conducted at the conclusion of the program, where they were asked open-ended questions about their research skill development, mentoring experiences, cleanroom training, and career interests.

Findings

1. *Increasing participant knowledge and professional development skills in microelectronics*

Quantitative Findings: All or nearly all REM participants (87.5 – 100.0%) reported growth in their research skills, including the ability to formulate research questions, use research-related tools, analyze research data, and interpret research results. Similarly, all or nearly all REM participants (87.5 – 100.0%) reported growth in their professional skills, including their ability to be innovative, take on leadership roles, collaborate with others, and manage time efficiently.

Qualitative Findings: When asked about how the program affected their research skills, REMs indicated that the program had a positive impact on their literature review skills (n = 2), critical thinking skills (n = 2), and their ability to conduct research independently (n = 2). For example, one participant explained,

> *"I would say it helped me to think in a deeper way, not just if this on surface, this doesn't work, we try the other one. It is like, why doesn't it work? We figure out why. Based on that why, we come up with a solution. It's more like the fundamental scientific method go into reality to me."*

2. Developing and foster best practices regarding the cleanroom

Quantitative Findings: Most REMs (85.7 – 87.5%) reported improvement in their understanding of microelectronics and Cleanrooms. All participants (100.0%) reported improvement in their ability to practice general lab safety, and many (71.5%) reported improvement in their ability to practice secure data management.

3. Improvement of mentoring practices

Quantitative Findings: Participants reported high levels of satisfaction with mentoring, where (87.5%) reported "good" or "excellent" support in their professional development and feedback on their performance. All participants (100.0%) "agreed" or "strongly agreed" that they received their desired level of mentorship. All participants (100.0%) reported "good" or "excellent" shared knowledge with their mentor.

Qualitative Findings: Through interviews with randomly selected participants, participants shared very positive experiences with their mentors. Participants described their mentors using terms such as excellent, active, communicative, and encouraging. Graduate student mentors also reported professional growth. For example, one mentor reflected:

> "*I think this mentorship experience was quite helpful for my skills as a mentor. It shifted many of my research problems from a reactive/problem-solving role to one more focused on being proactive and developmental. I had to be careful about planning experiments as much as possible to ensure good outcomes at the end of the short program."*

4. Increasing awareness of job opportunities in microelectronics.

Quantitative Findings: All program participants reported either planning to or already holding a career in a STEM-related field and/or a field relevant to microelectronics.

Qualitative Findings: In qualitative interviews, participants described expanded career interests, including a desire to pursue STEM pathways, a deeper understanding of research careers, and an increased motivation to seek future research experiences. For example, one participant noted:

> *"My participation in the Rice REM program has influenced me to pursue a STEM related career related to computer science. This program has made me interested in Electrical Engineering, Robotics and Biology."*

Limitations

Several limitations should be acknowledged. The sample size was small (N = 11) and drawn from a single institution, limiting generalizability. Findings are based primarily on self-reported measures, which may be subject to response bias. Additionally, data reflect short-term outcomes collected immediately after program completion; long-term impacts on academic and career trajectories were not assessed.

Conclusion and Future Directions

Overall, the findings demonstrate that the REM program was highly effective in advancing participants' research knowledge, professional competencies, and career awareness in microelectronics. Both quantitative and qualitative data indicate substantial growth in research skills, critical thinking, independence, alongside strengthened understanding of cleanroom practices and lab safety. Participants reported high levels of satisfaction with mentoring, and mentors themselves experienced meaningful professional development. Importantly, the program broadened participants' awareness of STEM and microelectronics career pathways. Collectively, these outcomes suggest that the program successfully integrated technical training, structured mentoring, and career exploration to foster both immediate skill development and long-term engagement in STEM.

Thus, our findings from the REM program demonstrate the potential of strengthening the STEM pipeline for through interdisciplinary research and mentoring experiences. By integrating authentic microelectronics research and structured mentorship, the program broadened access to high-impact research experiences and supported the development of microelectronics workforce skills. In doing so, the REM program contributes to national efforts to broaden participation in STEM and address critical workforce needs in microelectronics and semiconductor technologies.

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