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Strengthening STEM Instruction Through NSF TEACHER POWER RET with Hands-on Immersion Training in Semiconductor Electronics Research

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Abstract

The TEACHER POWER Research Experiences for Teachers (RET) program seeks to strengthen teacher capacity in engineering education by immersing middle and high school STEM teachers in authentic research experiences. The program is motivated by the growing national need to broaden participation in engineering and to better prepare K–12 educators to connect classroom instruction with real-world applications of engineering and technology. Prior research highlights the importance of sustained teacher engagement in research settings to improve STEM content knowledge, instructional practices, and student interest in engineering careers.

The TEACHER POWER RET program provides summer immersion experiences for teachers with follow-up academic year support to implement research-informed instructional modules in their classrooms. During Summer 2025, the first cohort of participating teachers engaged in multi-institutional collaborative semiconductor and electronic materials engineering-focused research projects with PIs, co-PIs, faculty mentors, graduate students, and undergraduate students. The design of the program emphasizes teacher integration into ongoing research, peer collaboration, and structured professional development sessions aimed at curriculum translation.

Preliminary findings from Cohort 1 suggest positive outcomes in teacher confidence, increased awareness of engineering practices in semiconductor workforce development, and the creation of classroom-ready instructional materials that reflect authentic problem-solving in electronic devices. Feedback from teachers also highlights the importance of community-building within the cohort and continued mentorship during the academic year. These early results are informing program adjustments as the team prepares for Cohort 2 in Summer 2026.

This work will present an overview of the program design, highlight key lessons learned from Cohort 1, and share emerging impacts on teacher practice. We will also discuss strategies for scaling and sustaining teacher-focused RET programs in engineering education settings.

Introduction

For over a decade, manufacturing innovation remains a cornerstone of United States economic growth, productivity, and global competitiveness [1-3]. Nowhere is this more evident than in the semiconductor sector, which supports nearly every modern industry, including defense, healthcare, energy, transportation, communications, and artificial intelligence [4-7]. Incremental growth in domestic semiconductor manufacturing generates economic impact, driving widespread economic benefits across related suppliers and industries, extending productivity benefits beyond manufacturing and industrial technologies [1,2,6].

Historically, manufacturing-led innovation has driven productivity gains faster than other industries, and semiconductor manufacturing continues to play a central role in advancing national productivity and technological leadership [1,2,8]. The resurgence of domestic manufacturing is not driven by low labor costs, but by technological sophistication [3,6,8]. Semiconductor manufacturing relies on highly automated, data-intensive, and precision-driven production environments that integrate robotics, artificial intelligence, advanced process control, nanotechnology, and novel materials [7-10]. As global competition intensifies, the ability of the United States to design, fabricate, package, and test advanced semiconductor devices increasingly depends on early adoption and continuous innovation in manufacturing and industrial technologies [4,6-8]. Consequently, semiconductor manufacturing is becoming more regionally concentrated, locating near research institutions, skilled workforces, and critical infrastructure to ensure supply chain resilience, national security, and economic stability [4,6,8,11,12].

Federal investments have accelerated the maturation of advanced manufacturing technologies, particularly in semiconductors [4,9,13]. National initiatives supported by the CHIPS and Science Act, the National Science Foundation, the Department of Defense, and the Department of Energy have reinforced public-private partnerships aimed at scaling semiconductor research, manufacturing, and workforce development [4,13-15]. Institutes and regional innovation ecosystems have emerged to foster collaboration among industry, academia, and government, recognizing that semiconductor leadership requires coordinated investments in technology, talent, and materials innovation [11,12,15].

Materials science has become a defining factor in the future of semiconductor manufacturing [7,10,16]. Continued advances depend on the development of materials that enable smaller feature sizes, improved energy efficiency, enhanced thermal management, greater durability, and sustainable manufacturing processes [7,10,16]. As device scaling and advanced packaging approaches increasingly encounter physical limits, progress is driven by innovations in materials and manufacturing processes rather than design alone [7,8,10]. Thus, the future role of the United States in semiconductor manufacturing is inseparable from leadership in materials research and advanced manufacturing technologies.

This new era of semiconductor manufacturing demands a highly skilled and adaptable STEM workforce [4,17,18]. However, the United States cannot meet current and projected workforce needs without broadening participation and strengthening STEM education pathways [17-20]. Persistent shortages of technicians, engineers, and materials scientists now pose direct constraints on semiconductor manufacturing capacity and competitiveness [6,14,17]. Addressing these challenges requires early and sustained engagement of students in STEM disciplines, particularly through K–12 education [19,20].

Because K–12 teachers play a critical role in shaping student interest and preparedness in STEM, it is essential that educators are equipped with current knowledge of semiconductor manufacturing, materials science, and related career pathways [19-21]. Research consistently shows that many teachers and students hold outdated or inaccurate perceptions of manufacturing, viewing it as low-skill or obsolete rather than technologically advanced and innovation-driven [18,21]. Professional development programs that immerse teachers in authentic semiconductor and advanced manufacturing research provide an effective mechanism for modernizing STEM instruction and aligning classroom learning with national workforce priorities [15,19,20].

Regional manufacturing ecosystems further amplify the impact of workforce development initiatives [11,12,15]. Areas with strong concentrations of research institutions, federal laboratories, and advanced manufacturing employers serve as innovation clusters that integrate education, research, and industry [11,12,15]. These ecosystems provide ideal environments for cultivating semiconductor talent pipelines, translating research into practice, and inspiring the next generation of scientists, engineers, and technicians [4,11,15,17]. Strategic investments in teacher preparation, materials and manufacturing education, and regional partnerships are therefore essential to sustaining U.S. leadership in semiconductor manufacturing and ensuring long-term economic and technological security.

Program Design and Objectives

The collaborative Research Experiences for Teachers (RET) program, TEACHER POWER (Preparing Our Workforce through Electronics and Research), utilizes electronic materials, packaging, and semiconductors (EMPS) as the unifying theme for teacher research experiences. This focus was intentionally chosen to align with regional workforce demands, existing research strengths, and the complementary expertise of the three participating universities. The primary objectives of this year-long program are to:

(1) support curriculum development and teaching by enabling RET participants to translate applied engineering research into inquiry-based, inclusive STEM curricula that reach more than 4,000 grades 6–12 students, with emphasis on minoritized and underserved populations, and to disseminate these materials through TeachEngineering and professional workshops;

(2) deepen participants’ engineering knowledge and team-based research skills, particularly within EMPS fields, while strengthening research ethics, technical communication, and collaboration with peers, mentors, and industry partners; and

(3) expand professional development and networking opportunities by fostering leadership skills and building sustained partnerships among K–12 educators, universities, industry, and the regional STEM ecosystem.

Participants engaged with three regional universities that have over a decade of collaboration providing highly successful RET programs [22-30]: a smaller public HBCU with approximately 1,600 undergraduate students (Central State University), a mid-sized private institution with approximately 7,000 undergraduates (University of Dayton), and a mid-sized public university enrolling approximately 8,000 undergraduates (Wright State University). Participants also completed site visits to four regional industries, one national research laboratory, and an affiliate regional university, all actively engaged in semiconductor and electronic materials research [31-50].

Year 1 Accomplishments

During the first year of the TEACHER POWER RET program, six grades 9–12 in-service STEM teachers and three pre-service teachers completed a six-week summer research immersion hosted across three regional universities. Participants were paired with faculty research mentors and engaged in projects aligned with regional strengths in electronic materials, advanced packaging, and semiconductor technologies.

Program Preparation and Orientation

Prior to the summer research immersion, participants completed a structured orientation designed to support cohort development, research readiness, and laboratory preparedness. Orientation activities included introductions to research teams; engagement with faculty mentors and program principal investigators; completion of required administrative documentation; participation in team-building and introductory design activities; and receipt of program logistics, schedules, and laboratory safety and cleanroom training. To strengthen foundational content knowledge, participants completed 20 hours of online semiconductor training through an affiliate university (University of Cincinnati), earning a microcredential certificate. This training was delivered as part of the OASiS Ohio Accelerator for Semiconductors and Integrated Scalable-Manufacturing in collaboration with the Intel Semiconductor Education Program and provided essential background in semiconductor materials, fabrication processes, and manufacturing concepts.

Summer Research Immersion Experience

The six-week research immersion was conducted from mid-June through late July 2025 and integrated hands-on laboratory research, structured professional development, and curriculum design activities. Participants engaged directly in research involving metals, nanoparticles, instrumentation, computational methods, and photonics, developing a deeper understanding of the role of electronic materials, packaging, and semiconductor technologies in modern society and advanced manufacturing. In parallel with laboratory research, participants received curriculum resources, ready-to-use classroom activities, and materials and supplies to support classroom implementation.

Research Teams, Professional Development, and Curriculum Translation

Participants were assigned to one of three interdisciplinary research teams, each consisting of two in-service teachers, one pre-service teacher, a faculty research mentor, and, when applicable, undergraduate researchers from complementary REU programs and graduate students. Each of the three collaborating universities hosted one team, and all conducted research in modern laboratory facilities under the guidance of their mentors. Year 1 projects focused on EMPS and included semiconductor fabrication and cleanroom experiences, synthesis and adhesion of silver nanoparticles on silicon wafers, and exploration of nanoparticles as foundational components of digital logic systems. Weekly industrial tours and curriculum workshops enabled participants to connect research activities to regional manufacturing and translate experiences into classroom-ready lessons for piloting and submission to TeachEngineering. The program concluded with a full-day research presentation and poster celebration, where participants shared their research findings and curriculum concepts with faculty, students, industry partners, and program stakeholders.

Post-Summer Outcomes
Following the summer experience, practicing RET teachers piloted curriculum materials in their classrooms and refined instructional content. All three curricula developed through the program successfully completed the TeachEngineering peer-review process and were accepted for publication in the TeachEngineering digital library. The curricula include *Rush Hour Mayhem*, *Beyond Binary: Building Blocks of Digital Decisions*, and *Photolithography Lab*. These resources will be publicly available for nationwide use.

Year 2 Improvements
Recruitment for the second cohort is completed and includes six in-service teachers and three pre-service teachers. Building on Year 1 lessons, the Year 2 program will implement targeted enhancements to strengthen participant preparation and research engagement. A key addition for Year 2 is a week-long EMPS boot camp at the start of the summer research immersion, delivered in collaboration with the OASiS Ohio Accelerator for Semiconductors and Integrated Scalable-Manufacturing. The TEACHER POWER RET is one of many programs supported by OASiS, a workforce initiative led by the University of Cincinnati with regional university, industry, community college, and K–12 partners. Founded in 2022 with initial support from Intel's Semiconductor Education and Research Program (SERP) for Ohio, OASiS is developing a workforce-ready talent pipeline across the semiconductor value chain and positioning Ohio as a national leader in the field. OASiS partners also recently released new semiconductor-focused micro-credentials through UC Skills, the University of Cincinnati's non-credit learning hub. During the boot camp, RET participants will join other regional educators for intensive professional development in semiconductor fundamentals, better preparing them for laboratory research and strengthening alignment with micro-credentials and classroom implementation.

Program Assessment and Key Outcomes
Assessment of Year 1 objectives is ongoing and includes qualitative and quantitative measures such as reflective surveys, pre-post program surveys of teacher attitudes and practices, content and pedagogical preparedness, classroom implementation, and perceived administrative support. Preliminary results indicate that the program met a majority of its stated objectives. Key outcomes include successful implementation of a multi-university collaborative RET model, development and publication of three inquiry-based curricula, early evidence of sustained teacher engagement with faculty and industry partners, and establishment of a new research collaboration between Central State University and Wright State University focused on silver nanoparticle synthesis and electrode applications.

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