Empowering Underrepresented Students through Hybrid Semiconductor Training: Outcomes from an NSF INCLUDES Initiative

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Empowering STEM Talent through Hybrid Semiconductor Training at FAMU: Outcomes from an NSF INCLUDES Initiative

Abstract:

The expansion of the U.S. semiconductor industry has intensified the demand for workforce development initiatives that prepare undergraduate students for advanced manufacturing careers. Supported by the NSF Eddie Bernice Johnson INCLUDES initiative, this project at Florida Agricultural and Mechanical University (FAMU), implemented a hybrid training model combining in-person fabrication experiences, online industry-aligned instruction, and structured mentorship. Eight undergraduate students participated during the 2024–2025 academic year. Post-program survey results indicated strong perceived learning support across components, with mentorship receiving the highest ratings. Students also reported high likelihood of recommending hands-on semiconductor training experiences. Findings suggest that hybrid, mentorship-driven models may support engagement and workforce readiness in semiconductor education pathways.

Keywords:

Semiconductor workforce development, Engineering technology, Mentorship, Microelectronics education

1. Introduction

National strategies to expand domestic semiconductor capacity have elevated workforce development as a central challenge for higher education and industry. Recent policy actions—including the CHIPS and Science Act—emphasize both manufacturing capability and talent development [1]. Industry analyses project that the U.S. semiconductor workforce will grow substantially by 2030, with tens of thousands of new technical positions at risk of going unfilled absent targeted education and training interventions [2], [3]. In parallel, national reports have underscored the need for coordinated, long-term approaches to microelectronics workforce development and training pathways [4].

This project addresses these needs through a hybrid training model for undergraduate students that integrates experiential learning, online industry-aligned instruction, and structured mentorship. The effort is aligned with the NSF INCLUDES initiative, which supports collaborative approaches to expand STEM participation and build inclusive pathways into STEM education and careers [5].

2. Literature Review

Experiential and active learning approaches are consistently linked to improved learning and performance in STEM contexts. Kolb's experiential learning theory emphasizes learning through concrete experience, reflection, and iterative application, providing a rationale for hands-on training environments [6]. In engineering education, active-learning strategies have been shown to improve student outcomes; for example, Prince synthesizes evidence supporting active, collaborative, and problem-based learning while noting implementation considerations [7]. Large-scale analyses in undergraduate STEM further demonstrate performance gains when active-learning methods are used instead of exclusively lecture-based instruction [8].

Mentorship is also widely recognized as a mechanism that supports persistence and success in higher education, particularly for STEM students. Crisp and Cruz synthesize mentoring research and highlight how mentoring can support academic integration, skill development, and career exploration through multi-dimensional support structures [9].

Workforce-development approaches that combine authentic practice, industry-aligned curriculum, and mentoring align well with recommended strategies for addressing semiconductor talent gaps [2], [3], [4] and with broadening participation goals advanced by NSF INCLUDES [5].

3. Program Description

The hybrid semiconductor training program was implemented across one academic year and consisted of three integrated components:

I. In-Person Semiconductor Fabrication Workshop

The hands-on fabrication experience was conducted at the University of Florida Nanoscale Research Facility, which houses advanced cleanroom infrastructure. Prior to travel, students participated in two 2-hour synchronous Zoom sessions focused on laboratory safety, cleanroom protocols, and foundational fabrication concepts. These sessions were attended by the eight participating students and faculty mentors to ensure readiness for facility engagement.

Following the preparatory sessions, students completed a two-day immersive workshop at the facility. Activities included exposure to cleanroom environments, wafer handling procedures, photolithography processes, nanoscale device fabrication demonstrations, and discussions of fabrication workflows. The workshop emphasized experiential learning, enabling students to connect theoretical semiconductor concepts with real-world manufacturing processes under supervised laboratory conditions.

II. Online Industry Bootcamp

The online bootcamp provided foundational semiconductor knowledge and industry context. Students engaged with modules covering semiconductor physics fundamentals, front-end and back-end manufacturing processes, fabrication ecosystems, and workforce pathways within the semiconductor industry. Instructional materials included curated tutorials, industry video content, guided readings, and applied exercises. The bootcamp was designed to prepare students conceptually for the fabrication experience while also broadening their understanding of industry expectations and career trajectories.

III. Structured Mentorship Model

Mentorship was embedded throughout the program to reinforce technical learning and support professional development. During the summer, students participated in biweekly Zoom mentoring sessions focused on technical clarification, career exploration, and reflection on workshop and bootcamp experiences. During the fall and spring semesters, mentorship transitioned to monthly meetings, conducted either virtually or in person, to monitor academic progress and sustain engagement in semiconductor-related pathways.

In addition to recurring meetings, students were provided with structured professional development opportunities, including interactions with researchers from Sandia National Laboratories and other industry professionals. These engagements supported career awareness, research exposure, and professional identity formation.
The coordinated integration of preparatory instruction, immersive laboratory experience, and sustained mentorship was designed to provide both technical competency development and long-term pathway support in semiconductor manufacturing.

4. Methods

Participants included eight undergraduate students during the 2024–2025 academic year enrolled in Electronic Engineering Technology and Electrical and Computer Engineering programs at Florida A&M University. All participants completed the full hybrid training sequence.

Program effectiveness was evaluated using a post-participation survey designed to assess perceived learning support and mentorship effectiveness. Items measuring workshop and bootcamp learning support and mentorship outcomes used a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). A separate item measured likelihood of recommending hands-on semiconductor projects using a 10-point scale (1 = Not Likely to Recommend to 10 = Highly Likely to Recommend). Quantitative responses were analyzed using descriptive statistics, including mean ratings and frequency distributions. Open-ended responses were reviewed using thematic analysis to identify recurring perceptions regarding program strengths and areas for improvement. Given the small cohort size (n = 8), findings are interpreted as exploratory and descriptive.

5. Results

Student perceptions of the hybrid training model were assessed using post-program survey responses (n = 8). Descriptive statistics for program components are presented in Tables 1–3.

As shown in Table 1, students reported strong perceived learning support across both instructional modalities. The in-person fabrication workshop received a mean rating of 4.75 (on a 5-point scale), while the online bootcamp received a mean rating of 4.62. These findings suggest that both experiential and online components were perceived as effective and complementary.

Table 1. Student ratings of program components (1=Strongly Disagree, 5=Strongly Agree).

Program component	Mean rating
In-person workshop learning support	4.75
Online bootcamp learning support	4.62
Overall mentorship experience	4.88

Mentorship outcomes (Table 2) were rated most highly among program elements. Students reported that mentorship was worth their time (M = 5.00) and engaging (M = 4.88), with high ratings for overall mentor effectiveness (M = 4.88). Ratings also indicated that mentors accommodated different learning styles (M = 4.62). These consistently high scores suggest that structured mentorship was a central strength of the program.

Table 2. Mentorship-related outcomes (1=Strongly Disagree, 5=Strongly Agree).

Mentorship dimension	Mean rating
Mentorship worth time	5.00
Mentorship accommodates learning styles	4.62
Mentorship activities engaging	4.88
Overall mentor rating	4.88

Recommendation data (Table 3) further reinforce overall satisfaction. All participants (100%) reported a likelihood rating of 9 or 10 (on a 10-point scale) when asked whether they would recommend hands-on semiconductor training projects over traditional laboratory activities.

Table 3. Likelihood to recommend hands-on projects (distribution; 1–10 scale)

Rating (1–10)	Number of students
1-5	0
6-8	0
9-10	8

These findings indicate consistently positive student perceptions across instructional modalities and mentorship components. The following discussion situates these outcomes within the broader literature on experiential learning, mentorship, and semiconductor workforce development.

6. Discussion

The findings suggest that the hybrid semiconductor training model was perceived as effective across its core components. Strong ratings for both the in-person fabrication workshop and the online bootcamp indicate that experiential and digital modalities can function complementarily when intentionally integrated. This aligns with prior engineering education research demonstrating improved engagement and learning outcomes through active and experiential approaches [6-8].

Mentorship emerged as a particularly influential element of the program. Consistently high ratings across mentorship measures support existing literature that frames mentoring as a multi-dimensional mechanism supporting academic integration, skill development, and career exploration [9]. The structured cadence of meetings and exposure to national laboratory researchers may have contributed to these perceptions by reinforcing professional identity and pathway clarity.

Within the context of projected semiconductor workforce shortages [1-4], hybrid models that combine immersive laboratory experiences with scalable online instruction and sustained mentorship may offer a practical framework for expanding advanced technical training. While the present findings are based on a small cohort and descriptive analysis, they provide preliminary evidence that coordinated, mentorship-driven semiconductor training initiatives are well received by undergraduate participants.

Future research should examine longitudinal outcomes, including persistence in semiconductor pathways, internship attainment, and continued engagement in research or industry-aligned experiences.

7. Conclusion

This study examined student perceptions of a hybrid semiconductor training model integrating preparatory online instruction, an immersive cleanroom-based fabrication workshop, and sustained structured mentorship. Descriptive findings from a pilot cohort suggest that students perceived strong learning support across instructional modalities, with mentorship identified as a particularly impactful component.

Although based on a small sample and exploratory analysis, results indicate that coordinated hybrid models may provide a viable framework for supporting undergraduate engagement in semiconductor-related pathways. The intentional integration of experiential learning, scalable digital instruction, and sustained professional mentorship represents a promising approach for institutions seeking to strengthen workforce preparation in advanced manufacturing fields.

Future work will extend this initiative by tracking long-term outcomes, including academic persistence, industry internships, research engagement, and continued participation in semiconductor-focused opportunities.

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