Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #48738

Integrating Microelectronics Into A First-Year Engineering Course For All Majors At Scale

Mr. Artre Reginald Turner, Purdue University at West Lafayette (COE)

Artre is a Ph.D. student in Engineering Education exploring how microelectronics curricula influence student learning, motivation, and transformative experiences. Beyond his lab-focused research, Artre is deeply interested in recreational video games and their potential to foster critical skills valuable to engineers and engineering students, particularly cognitive flexibility in problem-solving. His research seeks to understand how engaging with diverse recreational games can enhance problem-solving abilities, aiming to bridge the gap between leisure activities and academic performance.

Dr. Jason Morphew, Purdue University at West Lafayette (PPI)

Dr. Jason Morphew is an assistant professor at Purdue University in the School of Engineering Education. He serves as the director of undergraduate curriculum and advanced learning technologies for SCALE and is affiliated with the INSPIRE research institute for Pre-College Engineering and the Center for Advancing the Teaching and Learning of STEM. He serves as the course curator for the Freshman semester engineering design course that serves over 2,500 freshman engineering students every year. His award-winning teaching has been recognized for his teaching in the First Year Engineering program and is the Dr. Morphew has also recently taught courses focused on the pedagogy of integrated STEM and educational research methodology. Dr. Morphew's research focuses on the application of principles of learning derived from cognitive science and the learning sciences to the design and evaluate technology-enhanced learning environments. More specifically, his research examines the impact of technologies such as augmented-reality, gesture-based digital environments, microelectronics, and artificial intelligence on learning, interest, identity, motivation, and decision making in STEM. His research views learning through self-regulated learning, constructivist, and embodied cognition lenses.

Dr. Kerrie A Douglas, Purdue University at West Lafayette (PWL) (COE)

Dr. Douglas is an Associate Professor in the Purdue School of Engineering Education. Her research is focused on improving methods of assessment in engineering learning environments and supporting engineering students.

Integrating Microelectronics Into a First-Year Engineering Course for All Majors at Scale

Abstract

This Complete Research paper explores how integrating microelectronics into a first-year engineering course influences students' engagement, perceptions, and career pathways. Semiconductors, foundational to industries ranging from consumer electronics to national defense, require a robust workforce to meet growing demand. Initiatives like the CHIPS and Science Act of 2022 emphasize the need for domestic workforce development, but addressing workforce gaps requires early educational interventions to cultivate technical skills, persistence, and interest in microelectronics.

This study investigates how embedding microelectronics into an introductory engineering course can foster engagement and persistence. Using Social Cognitive Career Theory (SCCT) and a phenomenographic approach, the research examines (1) how prior experiences and barriers, such as access and social dynamics, affect students' engagement, self-efficacy, and learning outcomes, and (2) how perceptions of the personal, academic, and societal relevance of microelectronics influence their persistence and outcome expectations. Data was collected through semi-structured interviews with 18 participants from diverse backgrounds.

The findings, derived through two stages of structured coding with SCCT factors and pattern coding using thematic analysis, reveal that overall, students' interest and persistence regarding microelectronics either increased or remained consistent throughout the course. Disparities in access to microelectronics prior to the course shaped students' initial attitudes and engagement with the technology. Differences in prior experience with microelectronics and coding influenced how students navigated the course. The team-based format amplified these effects, leading to both increased and decreased engagement with the technology depending on group dynamics. Despite these disparities, students approached the course with varied levels of confidence and openness, shaped largely by their perceptions of personal, academic, and societal relevance.

This study underscores the potential of early microelectronics interventions to create equitable learning opportunities and foster a skilled engineering workforce.

Introduction

Microelectronics are part of everyday life, driving advancements across industries from consumer electronics to national defense. Despite being a global leader in microelectronics research and development, the U.S. share of semiconductor manufacturing fell to just 12% by 2020, with much of the production outsourced to overseas foundries such as Taiwan's TSMC [1]. The critical importance of locally manufactured microelectronics was brought into sharp focus during the semiconductor shortage of 2020, which exposed vulnerabilities in the global supply chain and highlighted the consequences of relying heavily on foreign manufacturing. The

---

We acknowledge the Silicon Crossroads Microelectronics Hub, Subagreement SA-22036, managed by the Applied Research Institute (ARI).

combination of limited domestic production capacity, and advancement in technologies such as artificial intelligence (AI) has exacerbated the gap between semiconductor supply and demand. In response, the United States government has made substantial investments to strengthen domestic semiconductor production, including initiatives such as the CHIPS and Science Act of 2022 [2]. However, the expansion of manufacturing capacity is expected to outpace the development of a workforce capable of supporting such rapid growth. The Semiconductor Industry Association projects a shortfall of 67,000 skilled professionals by 2030, with 51% of these positions requiring at least a four-year degree [3]. This pressing need highlights the importance of cultivating a workforce equipped to meet the growing demand for microelectronics professionals.

Educational interventions focused on college-level engagement with microelectronics will play a pivotal role in addressing gaps in workforce development. In the 2000s, several programs focused on the education and workforce development in microelectronics and semiconductor manufacturing [4], [5], [6]. However, many of these programs are now inactive or discontinued, and limited research exists on their long-term impact.

A recent study conducted by our team [7] found a significant increase in students' awareness, motivation, and transformative experiences related to microelectronics after participating in a first-year engineering course featuring microelectronics activities. A systematic review by Idem et al. [8] found similar outcomes, but found that several studies questioned the potential for these microelectronics activities to be scaled to large-enrollment courses.

This study explores the integration of microelectronics into a first-year engineering course as a means to influence students' career pathways and address workforce development challenges. The intervention introduces students to microcontrollers using scaffolded hands-on activities focused on developing visual modeling, coding logic, and engineering design skills. By scaffolding the microelectronic activities, this course design aimed to build technical skills and prepare students for future learning while fostering interest and self-efficacy in microelectronics.

This research examines how microelectronics activities shape students' interest, self-efficacy, and persistence in engineering. By focusing on first-year students, this study aims to understand how early educational experiences can spark long-term engagement with microelectronics and contribute to addressing the workforce challenges facing this critical industry. To examine how these activities influence students' engagement, self-efficacy, and perceptions of microelectronics, the research team aimed to answer the following research questions:

1. How do prior experiences and barriers (e.g., access, social dynamics) affect students' engagement, self-efficacy, and learning outcomes in microelectronics activities?
2. How do students' perceptions of the personal, academic, and societal relevance of microelectronics influence their engagement, persistence, and evolving outcome expectations?

Research Design

Theoretical Framework

This study was initially guided by Social Cognitive Career Theory (SCCT) [9], which provides a framework for understanding factors that influence career choices. SCCT describes how students' persistence in a career path emerges from the interaction of three domains: affective factors, personal variables, and environmental supports. Affective factors, such as self-efficacy (belief in one's abilities), interests (activity preferences), satisfaction (derived fulfillment), and outcome expectations (anticipated long-term benefits), are foundational for career motivation [10]. Personal variables like ethnicity or gender influence how students experience and interpret opportunities. Environmental supports—mentorship, peer encouragement, or institutional resources—serve to reinforce self-efficacy, amplify satisfaction, and generate outcome expectations with real-world possibilities. The relationships among these factors demonstrate the dynamic and interconnected nature of career development as outlined by SCCT (Figure 1).

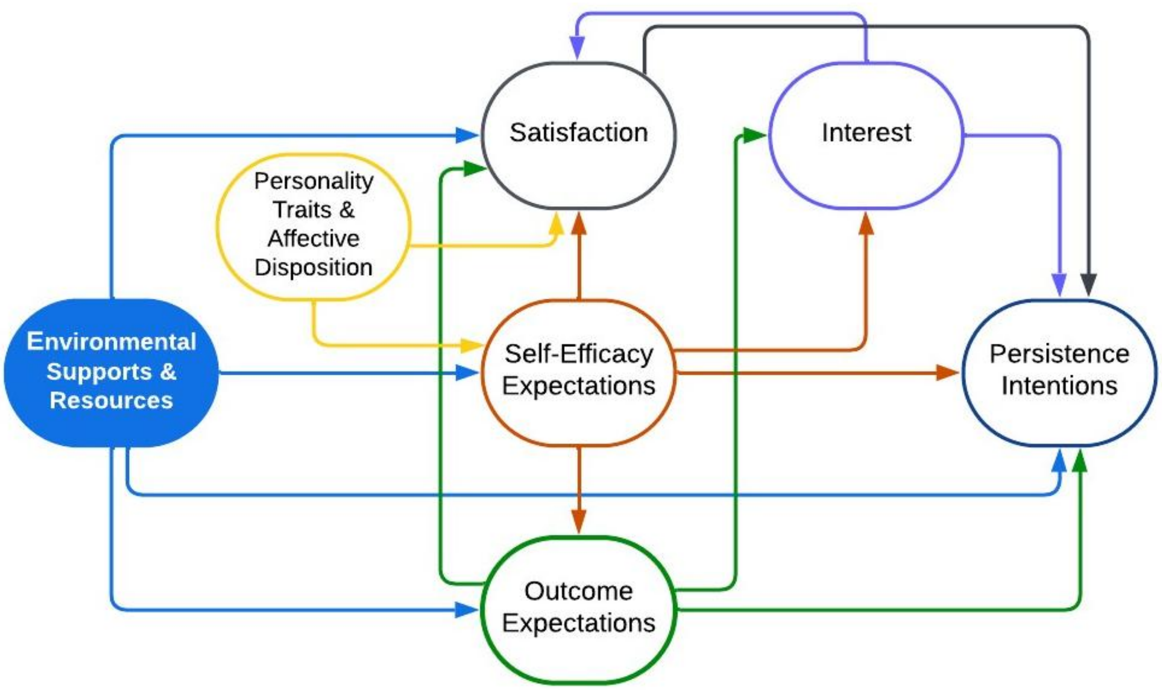

Figure 1. Social Cognitive Career Theory Map adapted from [11]

SCCT has been extensively applied across diverse contexts and has been used to understand career development, including for underrepresented groups in STEM fields [12]. In the context of microelectronics education, Gentry et al. [13] developed an instrument to assess students' exposure to and motivation for careers in microelectronics, aligning with SCCT's focus on self-efficacy, outcome expectations, and environmental supports. Their findings illustrate how SCCT can be used to explore career-related decision-making in technical fields. Similarly, this study applies SCCT to investigate how microelectronics activities in a first-year engineering course influence students' engagement, confidence, and career aspirations.

Description

The course, titled ENGR 131: Transforming Ideas to Innovation, is an introductory engineering course designed for first-year students. The learning objectives of the course include data analytics, physical and mathematical modeling, and engineering design. In the fall, this course enrolls more than 2,000 students across several sections. In the spring, during which this study occurred, 84 students were enrolled. These students were organized into teams of three or four students and were supported by a teaching staff comprising one instructor, one graduate teaching assistant, and four undergraduate teaching assistants. Over the past three semesters, the course has integrated three hands-on microelectronics activities into its curriculum. These activities are designed to equip students with foundational engineering skills, including modeling complex systems, data collection and analysis, and engineering design. Additionally, the activities introduce students to cutting-edge microelectronics technologies, such as microcontrollers, providing early exposure to tools and techniques critical to modern engineering practices. At the core of these activities are Texas Instruments microcontrollers, versatile tools that enable students to prototype automated designs as well as collect data about the effectiveness of their designs. By bridging theoretical knowledge with practical application, these activities provide students with opportunities to develop both technical skills and problem-solving abilities.

Participants

The participants in this study were drawn from a first-year engineering course at Purdue University, West Lafayette. Eighteen students were recruited through an in-class announcement delivered at the beginning of one course section. Sixteen of the participants were first-year students, while the remaining two were transferring into engineering. All participants were over the age of 18. Demographic information for participants was obtained from the learning management system and is presented in Table 1.

Table 1. Participant Demographics

Pseudonym	Gender	Race/ethnicity	Major	Intended Major (Engineering)
Avery	Woman	Caucasian	FYE	Industrial
Blair	Man	Asian	FYE	Mechanical Engineering
Casey	Woman	Indian American	FYE	Electrical & Computer
Dakota	Woman	Asian	Psychological Sciences	Electrical & Computer
Emery	Man	Caucasian	FYE	Aerospace
Finley	Woman	Asian	FYE	Electrical & Computer
Grey	Man	Asian	FYE	Electrical & Computer
Hayden	Man	Asian	FYE	Aerospace
Indigo	Man	Caucasian	FYE	Industrial
Jordan	Woman	Asian - Indian	FYE	Civil
Kai	Man	Caucasian	FYE	Mechanical
Logan	Man	Caucasian	FYE	Aerospace
Morgan	Man	Caucasian	FYE	Mechanical or Agricultural
Noel	Man	Caucasian	FYE	Biomedical or Biological

Oakley	Man	Caucasian	Pre Ag & Bio Engineering	Biological
Phoenix	Man	Asian	FYE	Aerospace
Reese	Woman	African American	FYE	Chemical
Skyler	Woman	Caucasian	FYE	Industrial

Note: FYE = First-year Engineering. Dakota and Oakley are transfer students into engineering

We were fortunate that the diversity of participants reflected the broader population of first-year engineering students. Each participant took part in a semi-structured interview, which lasted between 10 and 30 minutes depending on the depth of their responses. To acknowledge their time and effort, participants were compensated with a $20 cash payment upon completing the interview.

This work involved human subjects in its research. Approval of all ethical and experimental procedures and protocols was granted by the Institutional Review Board (IRB-2024-237).

Data Collection – Semi-structured Interviews

Data for this study were collected using semi-structured interviews designed to explore students' experiences with microelectronics in the course. This approach provided a flexible framework, encouraging participants to share detailed reflections on their prior exposure to microelectronics, their evolving interest in the subject, and their future engagement plans. The semi-structured format allowed interviewers to ask follow-up questions, tailoring discussions to the unique experiences and perspectives of each participant. This method ensured the collection of rich, nuanced data that captured both individual and shared experiences, providing valuable insights into the impacts of the course's microelectronics activities.

The development of the interview protocol was a collaborative effort by the research team, informed by previous survey items, response analysis, and insights from existing SCCT literature. The survey included short response questions that highlighted key themes regarding microelectronics perceived impacts. Responses from several sections of the survey helped identify topics that could be expanded upon in the interviews.

The protocol was designed to explore three primary topics: students' prior exposure to microelectronics and programming, their experiences and attitudes during the course (ENGR 131), and their plans for future engagement with microelectronics, such as hobbies or career aspirations. Specific questions addressed students' self-efficacy and interest in microelectronics, the perceived relevance of course activities, and how these factors influenced their academic and career decisions. The protocol included twenty-two open-ended questions, such as "What experiences did you have with microelectronics prior to this course?" and "How did your feelings about microelectronics change over the semester?" Each question had up to three follow-up prompts to encourage deeper reflection and capture nuanced perspectives.

Before recording interviews for this study, we conducted four pilot tests with students who had previously taken the course. These tests helped refine the interview protocol and provided the research team with additional practice, complementing internal interview training sessions. This iterative process ensured the protocol effectively captured meaningful insights while aligning with the study's objectives of examining how microelectronics activities influenced students' engagement, confidence, and career pathways.

Following the interviews, recordings were transcribed using an AI-assisted tool, Rev AI. Members of the research team manually reviewed each transcript to verify the accuracy and completeness of the transcripts. Once verified, the transcripts were imported into NVivo, a qualitative data analysis software, where they were securely stored and analyzed.

Data Analysis

Data analysis was conducted in two stages: deductive structured coding and inductive pattern coding. In the deductive stage, the research team applied structured coding based on the six key factors of SCCT: self-efficacy, outcome expectations, interests, satisfaction, persistence, and environmental supports. This stage allowed for the systematic exploration of how students' experiences with microelectronics activities related to SCCT constructs. Definitions for each factor were collaboratively refined to ensure consistency during coding and to capture nuanced data points accurately and are shown in Table 2.

Table 2. Social Cognitive Career Theory Structured Codes

Category	Defining Criteria	Example Quote
Self-Efficacy	Students' confidence in their ability to complete their engineering/major coursework (microelectronics)	"I never used them (microelectronics) but I feel like I'll do fine in the course"
Outcome expectations	Beliefs about the impact of microelectronics activities/knowledge on their lives, career, and education	"I want to do biomedical so I can create solutions for individuals in need"
Interest	Student's interest in microelectronics	"I don't see myself using microelectronics in my career"
Satisfaction	Student's satisfaction or affect with the microelectronics activities	"I still don't feel like I know what I'm doing with them (microelectronics)."
Persistence	Students desire to persist with microelectronics in some capacity	"I'm interested in doing some research with microelectronics"
Environmental supports and resources	Supports available to students regarding microelectronics, including access to microelectronic related courses	"My classmates help me understand the assignment"

As the analysis progressed, the need for a grounded approach became apparent. During the analysis of interview data, the depth of student responses revealed aspects of the microelectronics activities and course structure that seemed to impact how students engaged with the activities and the learning outcomes they experienced. During our deductive coding, themes emerged that extended beyond the scope of the original SCCT framework. These additional themes prompted a shift toward phenomenography to better capture the diverse experiences and perceptions of the participants. Phenomenography, which focuses on understanding variations in how individuals experience and interpret phenomena, provided a more flexible lens for exploring the rich and nuanced data from the interviews.

The inductive pattern coding stage was largely guided by Miles and Huberman [14], emphasizing the generation of themes directly from the data. During this stage, the research team built on insights gained from the structured coding process and became deeply familiar with the data through iterative reviews. Pattern coding was employed to group related responses and identify recurring themes. This stage of analysis provided flexibility to uncover patterns and relationships that extended beyond the SCCT framework, offering richer insights into the ways microelectronics activities influenced students' career aspirations and engagement (Table 3).

Table 3. Pattern Codes

Theme	Defining Criteria	Subcategories
Connections with Microelectronics	Things students relate to or compare with microelectronics	Specific Technology Courses, Clubs, Subjects Majors or Careers
Perceived Relevance	How important does microelectronics and/or learning about microelectronics appear to students.	Professionally, Academically, Personally Life & Society
Barriers to Engagement	Things that prevent students from engaging with microelectronics	Access Social & Team Confidence/Self-efficacy
Student Expectations	Things students expected out of the microelectronics experience in the course	Enjoyment Difficulty Technical
Openness to Persist	The student expresses openness to persisting with microelectronics in some capacity	Major Persistence (Career) Minor Persistence (Research) Joining Organization

In this study, the combination of thematic analysis and phenomenography allowed the research team to strike a balance between a theoretically grounded framework and being responsive to the emergent nature of the participants' experiences. Specifically, SCCT provided an initial structure for understanding the career-related impacts of microelectronics activities, while the phenomenographic perspective enabled a deeper exploration of the themes that surfaced organically during analysis. This dual approach ensured a comprehensive understanding of the data, addressing the study's research questions while remaining open to new discoveries.

Results & Discussions

This section explores how integrating microelectronics into a first-year engineering course influenced students' engagement, self-efficacy, and outcome expectations. Drawing on qualitative data from semi-structured interviews, we examine how prior experiences, team dynamics, and perceptions of relevance shaped students' interactions with microelectronics activities. The findings are organized around two key research questions: (1) how prior experiences and barriers, such as access and social dynamics, affected students' engagement and learning outcomes; and (2) how perceptions of the personal, academic, and societal relevance of microelectronics influenced their persistence and evolving career expectations. Together, these results provide insights into the benefits of embedding microelectronics in foundational engineering education, as well as the challenges and opportunities for improving student outcomes.

R1. How do prior experiences and barriers (e.g., access, social dynamics) affect students' engagement, self-efficacy, and learning outcomes in microelectronics activities?

Student Outcomes

Using the SCCT framework, this analysis highlights how microelectronics activities influenced students' self-efficacy, interests, and outcome expectations. All participating students expressed some level of enjoyment with the course and the microelectronics activities. The participating students remarked how the microelectronics activities helped foster a sense of accomplishment and curiosity, and reinforced students' confidence in their engineering abilities. For example, Logan reflected on how the hands-on nature of the activities enhanced their self-efficacy and made abstract concepts more engaging:

> "I really liked being able to see a physical translation between code and what actually happens, rather than just seeing a number get displayed on the screen. It was kind of fun to hear the buzzer beep to a song or see the detector work. It made coding a little more fun."

Multiple participants echoed this sentiment, with many noting how the activities provided opportunities to connect theoretical knowledge with practical application, enhancing their outcome expectations. For instance, Avery shared:

> "The first ones were a little rough, but now they go pretty smoothly. We work as a team so we all know like, 'you find the sensors, you put it together, and then you run it on our computers."

The participants noted that the activities helped improve their technical skills, interest, and self-efficacy. In addition, several participants noted that the scaffolding of the activities had a large impact on students with little prior experience in microelectronics or coding. For example, Skyler highlighted how these activities deepened their interest in microelectronics and increased their persistence with the technology:

> "I actually still love growing and learning about them more. I felt like the first few activities he like really walked through it like step by step, which was really helpful. I could see that if somebody was like, just starting, that would be a good way to like kind of like transition and then dip your toes in, especially for someone who's never worked with it before. So, they did a pretty good job so I felt comfortable with it.

Overall, the microelectronics activities provided participants with valuable technical exposure while enhancing their confidence, interests, and outcome expectations. However, some participants describe various barriers that prevented them from engaging completely with the microelectronic activities.

Barriers to Engagement - Prior Experience

The participants entered ENGR 131 with a range of prior exposure to microelectronics and coding. While a few participants gained experience through high school classes, structured programs, or personal projects, most participants did not have opportunities for hands-on engagement with microelectronics or coding before this course. For example, Finley, who attended a resource-limited school, described their lack of access to microelectronics:

> "I had no experiences whatsoever because originally, I came from Korea and I was in a public school, which means like they don't have enough resources to actually do hands-on stuff. So, we only learned theoretical stuff, and then all those hands-on things like microelectronics were not in the picture."

Finley's account highlights how systemic inequities in resource availability prevents many students from engaging with microelectronics. Without access to microelectronics, students not only enter engineering at a disadvantage compared to peers who had prior exposure, but also impacts the engineering pathways and careers that first-year engineering students feel they can access. In the interviews, some participants discussed how a lack of prior knowledge and access impacted their approach and engagement with the course. For example, Logan expressed their lack of access to microelectronics:

> "I don't think I had any experience with microelectronics. I think I have just heard about them and I did some research for like a few different research papers on how to apply some of my ideas for what to fix about random topics like climate change or plastic waste, that kind of thing. But I never actually was able to use microelectronics."

When asked whether anything actively discouraged them from learning about microelectronics, Logan described how their limited access restricted their prior interest in engaging with microelectronics by saying, “I think it's just because I didn't really know what they were or like have access to them, so I just never really—it just didn't seem like something I’d use myself.”

Logan’s remarks illustrate how the absence of hands-on opportunities not only limited their technical familiarity but also shaped their perceptions of microelectronics as inaccessible or irrelevant. This lack of hands-on experience with microelectronics highlighted a gap between theoretical knowledge and practical experience that left some students feeling disconnected from the technology. These disparities reinforced the importance of equitable access to hands-on opportunities in developing students’ familiarity with technology and their willingness to engage. Avery, like many participants, reflected on how access to hands-on activities using microelectronics within the course sparked curiosity and motivation to learn. Avery reflected on their feelings when encountering microelectronics in this course:

> “I was excited because I heard other schools had it [microelectronics] and they all enjoyed it. They got to work with it in middle school and high school, and I never got to, so I've always been curious about that.”

While Avery’s response is very explicit, it reflects the experience of roughly half of the participants and highlights the multifaceted impact of access disparities. Avery, like many other interviewees, viewed the course as an opportunity to explore what they had previously missed. This initial curiosity served as a motivator to engage with the microelectronics activities despite initial disadvantages.

Barriers to Engagement - Social & Team Barriers

The team-based structure of the course was intended to provide scaffolding to students with less experience through peer support. This was the case for many participating students as the collaborative nature of the microelectronics activities provided valuable opportunities for learning and support. This is highlighted by Jordan who described how their teammates contributed to their understanding:

> “I don't know if they'd be interesting if I was doing it alone… I did it with my team. And I get pretty along with them and it was really fun. Like they know stuff and they teach me that stuff. So, I think I learned pretty quickly that way.”

Finley similarly reflected on how collaboration improved their experience over time:

> “There was just a lot of information to take in about like the microcontroller kits. And yeah, pretty confusing. But then as we went on, it became better… it was like at the point when we actually got teams for the whole semester, and then we started to work on TI kit in-class activities every now and then. And my teammates sort of helped me like understand like especially like how the algorithms work.”

These examples highlight how supportive team dynamics can mitigate some of the initial barriers to engagement. For students with less prior experience, working collaboratively allowed them to build understanding and confidence over time. However, while the team-based structure of the course provided scaffolding and support for many students, this structure also introduced unexpected challenges for others. In teams where one student had extensive microelectronics or coding experience, students with less experience would often defer to their more knowledgeable teammates by limiting their engagement with the microelectronics activities. For example, Kai explained their reluctance to participate in microelectronics tasks by saying, “I think just because I've had very little experience and I just don't remember any. I know I've had some like MATLAB experience and like Arduino… I just don't remember much of it. Sure. So that definitely felt intimidating.”

When asked to explain, Kai elaborated on how this influenced their role within the team:

> “Being around people who know how to do it very quickly, I don't really want to be that kind of kid who's, you know, just spending 20 minutes trying to figure out how to do it when someone else knows how to do it in 10 seconds. You know, so sometimes it's just for the better of the group when you just let someone who already knows how to do it, do it, and then get done with the assignment quicker.”

Interestingly, it didn’t always take significantly more experience for a student to defer working with the microelectronics. Sometimes, even minor perceived differences were enough to create this dynamic. When asked how they engaged with the microelectronics activities, Reese reflected on their role within the team by saying, “I feel like I did OK. I'm not like, I'm not the dominant person in our group or who's working with it. I try—I kind of try to avoid it.” However, when asked if someone in their group had more experience, Reese explained, “All of us are kind of on the same level, to be honest, but one of them does. Like, has done a coding class before and has a little bit more experience.”

These responses demonstrate how differences in prior experience can lead students to avoid engaging with microelectronics, deferring to teammates they perceived as more capable. Even when differences in experience were minor, the structure of the course allowed some students to avoid working directly with the technology.

Barriers to Engagement - Technical Barriers

Surprisingly, technical issues were mentioned infrequently and did not appear to hinder overall engagement for these participating students. While these barriers were occasionally frustrating, they were typically resolved quickly and did not leave lasting impacts on students’ overall experience or engagement with the course. For example. Avery described encountering early difficulties with the microelectronics tools by saying, “I think I liked it [the activities] but was a little bit confused about most of it because it didn't work on my laptop, so I looked off of other people's.”

R2. How do students' perceptions of the personal, academic, and societal relevance of microelectronics influence their engagement, persistence, and evolving outcome expectations?

Participating students' perceptions of the relevance of microelectronics to themselves, their academic fields, and society played a meaningful role in shaping their persistence, willingness to engage with the activities, and the students' outcome expectations. These perceptions varied widely, with attitudes appearing to be related to the participant's individual interests and career goals.

Relevance of Microelectronics

Participating students connected microelectronics to their academic and career aspirations in various ways. The connections that participants made appear to influence their engagement with the technology and the activities. For most students, microelectronics was perceived to potentially align with their intended major and career. This alignment seems to help foster student interest and persistence. Blair, for example, expressed enthusiasm about its importance to their future in electrical and computer engineering:

> "I'm interested in electrical or computer engineering, which deals with lots of chips. My future goal is to take electronic parts, make casing, and build a product. I think it's going to include a lot of microcontroller units."

This alignment motivated Blair to engage deeply with the microelectronics activities, viewing them as foundational to their career aspirations. In contrast, participants whose intended majors were perceived to be unrelated to microelectronics sometimes struggled to connect the activities to their future in engineering. For example, Avery, who had decided to major in industrial engineering, reflected, "I already knew what I wanted to go into, so I wasn't really considering electrical, so it [the activities] didn't change that, but it was a fun experience."

For Avery, engagement with microelectronics remained limited to fulfilling course requirements, without influencing their academic trajectory. Their perceived connection of microelectronics to electrical engineering decreased their willingness to persist. For others, the course affirmed their decision to pursue fields outside of electrical engineering. Kai noted, "I think it definitely turned me off from ECE," highlighting that their experience with microelectronics solidified their lack of interest in the subject:

These contrasting perspectives highlight how personal relevance can both inspire and inhibit engagement with microelectronics, depending on how well students perceive its alignment with their academic and career goals.

Beyond personal career goals, half our participants described the broader societal importance of microelectronics, which influenced the extent to which they engaged with the technology and activities. For example, Logan reflected on the practical applications they observed during the course, explained how learning about the societal relevance of microelectronics broadened their interest:

> "It made me want to use them [microelectronics] more often because I saw a better application for them... like you could use a radar range sensor like they use in the scanners for cars to detect that. So, seeing how applicable it is made me want to use it [microcontrollers] more and kind of understand them."

Similarly, Morgan stated, “I know it's [microelectronics] a very important thing to be an engineer, especially in today's world," emphasizing the significance of microelectronics within the engineering profession. For students like Logan and Morgan, recognizing societal relevance provided motivation to engage with microelectronics, even if their personal interest was limited. In addition, increases in student interest over the course of the semester was often rooted in an appreciation of how microelectronics contribute to other technological advancements was common to many of the students. These examples demonstrate how perceptions of microelectronics’ broader impact can influence engagement by situating the technology within a larger societal framework. In addition, it is important to incorporate instruction about the relevance of microelectronics in real-world contexts using hands-on microelectronics activities.

Shifting Outcome Expectations

While not as common as interest, enjoyment, and learning outcomes, some participating students experienced a change in their outcome expectations surrounding microelectronics. These changes appeared to be related to a reduction in anxiety about incorporating microelectronics into their future careers, leading to a strengthening interest in microelectronics. For example, Noel, who was considering biomedical engineering, reflected on how the course influenced their perspective, "Prior to this, I had very little interest in electronics at all; and then now I have interest in electronics specifically applied [to] biomedical... I'm just less anxious about it now." For Noel, the hands-on experience of using microelectronics in an engineering course alleviated concerns about working with electronics in their intended career. This reduction in anxiety appears to have led to the prospect of incorporating microelectronics into biomedical applications less intimidating. Similarly, Dakota, reflected on how engaging in hands-on microelectronics activities deepened their existing interest in electronics. For example, when asked how her interest in microelectronics changed over the semester, Dakota said, "It strengthened my interest in electronics. Before, I didn't know much about microelectronics, but Purdue introduced me to it, making me more interested." For Dakota, the course experience reinforced their academic and career aspirations, solidifying their enthusiasm for pursuing electronics more deeply.

Indigo, who was already decided to major in industrial engineering, also described how the microelectronic activities may have played a small role in their outcome expectations for using microelectronics by saying, “Microelectronics influenced it maybe a little bit, not a whole ton... but it will definitely be involved with industrial engineering." Indigo highlights how the activities help him recognize the relevance of microelectronics to their intended engineering field. Even though the experience did not alter Indigo’s academic trajectory, the activities broadened Indigo's understanding of how microelectronics intersect with other engineering disciplines.

Despite these shifts in perceptions, most participating students did not intend to change their majors as a result of the course. Apart from Noel, who was still deciding between majors, participants generally viewed the microelectronics activities as supplementary rather than transformative to their academic or career trajectories.

Similarly, when reflecting on skills gained during the course, participating students perceived limited outcome expectations regarding coding abilities. Students were introduced to common coding logic structures, such as loops, selection statements, and functions, but they did not learn to code in Arduino explicitly; instead, they modified a repository of sample code. As a result, most participating students perceived the coding experience in the microelectronics activities as insufficient preparation for future coursework. However, this perception was potentially based on their current understanding, as many had not yet taken a formal coding course at the time of the interview. Some students, however, were more optimistic. For example, Reese indicated that she learned some useful coding skills: "I guess using Energia and just like knowing how to maybe stop the code, just like basic stuff about programming."

Conclusion

This study highlights how integrating microelectronics into a first-year engineering course can influence students' engagement, persistence, and evolving career expectations. By examining barriers such as disparities in prior access and the dynamics of teamwork, as well as the role of perceived relevance, the findings underscore the complexities of fostering meaningful engagement in engineering education. These findings highlight the challenges associated with expanding microelectronics instruction to large-enrollment courses (e.g., [15]).

The interviews revealed that barriers related to prior experience influenced how participating students engaged in the microelectronics activities. Disparities in previous access to microelectronics shaped how participants approached the course, with limited access often leading to lower self-efficacy and reduced engagement. However, for some participants, curiosity and a growth mindset resulted in overcoming their access barrier, driving them to actively explore microelectronics for the first time. Social dynamics within teams played a dual role, as participants with less experience sometimes deferred to more knowledgeable peers, limiting their hands-on participation. On the other hand, some teams found that the more knowledgeable team members did not take over but rather supported the other team members in exploring and using the microcontrollers. In these cases, participants with less experience saw greater gains in interest, motivation, and perceived relevance. This demonstrates that team dynamics is important to support when incorporating microelectronic activities, and critical when scaling these activities for large enrollment courses.

Unexpectedly, technical barriers were only occasionally mentioned, and participants reported that they were quickly resolved and had a minimal impact on engagement. While some participants did not perceive learning of technical skills, or anticipate direct academic benefits from the coding aspects of the course, others found this learning to be invaluable. As the longitudinal impact of microelectronics activities is beyond the scope of this paper, future research should examine the longitudinal outcome as students enroll in the second semester engineering course that focuses on teaching coding. Regardless of student perceptions about technical skills, participating students did enjoy the development of other transferable skills like teamwork and communication developed through microelectronics activities.

Participating students’ experiences also revealed that both access to microelectronics and the alignment of microelectronics with personal, academic, and societal goals shaped students’ willingness to engage and their outcome expectations. For some, alignment between microelectronics and their career aspirations motivated deeper engagement, while for others, their inability to see the connection with their career aspirations led them to engage less with the hands-on activities. However, for students who do not automatically see connections to microelectronics, the inclusion of several discussions about how microelectronics is used across engineering domains resulted in connections to societal relevance. Societal relevance emerged as an important factor, with several participants expressing increased interest and persistence after recognizing microelectronics' broader applications and contributions to engineering and technology. This underscores the multifaceted role of perceived relevance in shaping students’ experiences and highlights the importance of designing activities that connect technical skills to both individual goals and societal impact.

These findings emphasize the importance of early, hands-on interventions in creating equitable opportunities and cultivating a future workforce equipped to address critical challenges in microelectronics and engineering. In addition, these results underscore the critical role of equitable access and environmental support in shaping students’ persistence and success in microelectronics activities. Finally, this study highlights the critical importance of engaging younger students, particularly those in K-12 contexts, in microelectronic activities before they have finalized career decisions to address the growing need for a large and diverse set of microelectronics engineers and technicians.

Limitations

This study, like all studies, has limitations. All participants were drawn from a single spring course section, which had smaller class sizes and a single instructor, potentially limiting the generalizability of the findings. Additionally, the cross-sectional design prevents tracking long-term career trajectories and the sustained impact of microelectronics activities. Selection bias is also a concern, as students who volunteered may have had more positive experiences or a stronger interest in microelectronics.

References

[1] A. Varas, R. Varadarajan, J. Goodrich, and F. Yinug, "Government Incentives and US Competitiveness in Semiconductor Manufacturing," Boston Consulting Group X Semiconductor Industry Association, Sep. 2020. Accessed: May 17, 2024. [Online]. Available: https://www.semiconductors.org/wp-content/uploads/2020/09/Government-Incentives-and-US-Competitiveness-in-Semiconductor-Manufacturing-Sep-2020.pdf

[2] T. [D-O.-13 Rep. Ryan, *Chips and Science Act*. 2022. Accessed: May 09, 2024. [Online]. Available: https://www.congress.gov/bill/117th-congress/house-bill/4346

[3] "Chipping Away: Assessing and Addressing The Labor Market Gap Facing the U.S. Semiconductor Industry," Semiconductor Industry Association & Oxford Economics, Jul. 2023. Accessed: May 09, 2024. [Online]. Available: https://www.semiconductors.org/chipping-away-assessing-and-addressing-the-labor-market-gap-facing-the-u-s-semiconductor-industry/

[4] S. Kurinec, M. Jackson, T. Schulte, N. Kane, E. Lewis, and S. Gupta, "Microelectronic Engineering And Nanotechnology Education For Undergraduates And Pre College Students Through Curriculum Reform And Outreach Activities," in *2008 Annual Conference & Exposition Proceedings*, Pittsburgh, Pennsylvania: ASEE Conferences, Jun. 2008, p. 13.893.1-13.893.8. doi: 10.18260/1-2--3450.

[5] S. Sarin, L. Guido, J. Heflin, and R. Hendricks, "An Interdisciplinary Curriculum For Microelectronics," in *2001 Annual Conference Proceedings*, Albuquerque, New Mexico: ASEE Conferences, Jun. 2001, p. 6.175.1-6.175.9. doi: 10.18260/1-2--9453.

[6] G. Tait and D. McBride, "NSF programs in microelectronics and semiconductor manufacturing education," in *Proceedings of the Fourteenth Biennial University/Government/Industry Microelectronics Symposium (Cat. No.01CH37197)*, Richmond, VA, USA: IEEE, 2001, pp. 20–24. doi: 10.1109/UGIM.2001.960286.

[7] A. R. Turner, B. A. Tanay, K. A. Douglas, M. A. Dyehouse, and J. W. Morphew, "WIP: Microelectronic Integration in First Year Engineering Education Curriculum for SCALE," in *2024 IEEE Frontiers in Education Conference (FIE)*, Washington, DC, USA: IEEE, Oct. 2024, pp. 1–5. doi: 10.1109/FIE61694.2024.10893403.

[8] U. # Idem, Ş. Purzer, and J. W. Morphew, "How Microelectronics and Microcontrollers are Integrated into First-Year and Sophomores Engineering Programs.," unpublished, to be presented at the ASEE 2025,

[9] R. W. Lent, S. D. Brown, and G. Hackett, "Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance," *J. Vocat. Behav.*, vol. 45, no. 1, pp. 79–122, Aug. 1994, doi: 10.1006/jvbe.1994.1027.

[10] R. W. Lent and S. D. Brown, "Applying Social Cognitive Theory to Career Counseling: An Introduction," *Career Dev. Q.*, vol. 44, no. 4, pp. 307–309, Jun. 1996, doi: 10.1002/j.2161-0045.1996.tb00447.x.

[11] R. W. Lent *et al.*, "Social cognitive predictors of adjustment to engineering majors across gender and race/ethnicity," *J. Vocat. Behav.*, vol. 83, no. 1, pp. 22–30, Aug. 2013, doi: 10.1016/j.jvb.2013.02.006.

[12] N. A. Fouad and M. C. Santana, “SCCT and Underrepresented Populations in STEM Fields: Moving the Needle,” *J. Career Assess.*, vol. 25, no. 1, pp. 24–39, Feb. 2017, doi: 10.1177/1069072716658324.

[13] A. Gentry, P. Bermel, E. Holloway, and K. Douglas, “Validity Evidence for Exposure and Motivation Scales in a Microelectronics Workforce Development Program,” in *2022 ASEE Annual Conference & Exposition Proceedings*, Minneapolis, MN: ASEE Conferences, Aug. 2022, p. 40872. doi: 10.18260/1-2--40872.

[14] M. B. Miles and A. M. Huberman, *Qualitative data analysis: An expanded sourcebook, 2nd ed.* in Qualitative data analysis: An expanded sourcebook, 2nd ed. Thousand Oaks, CA, US: Sage Publications, Inc, 1994, pp. xiv, 338.

[15] M. M. U. Faiz, D. M. S., A. Zerguine, M. R., R. R. Singh, and S. S., “Implementation of an Effective Project-Based Learning Methodology in the Freshman Year of Engineering and Technology Programs,” in *2023 IEEE Frontiers in Education Conference (FIE)*, College Station, TX, USA: IEEE, Oct. 2023, pp. 1–7. doi: 10.1109/FIE58773.2023.10343089.