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WIP: Impacts of Microelectronics Curriculum for a First-Year Engineering Course for All Majors: A Longitudinal Extension

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Introduction

This work in progress research paper investigates how a microelectronics intervention influences the career choices of students in a first-year engineering course. Engineering and technology are fundamental drivers of societal progress and economic vitality, creating an ongoing need for a well-prepared engineering workforce capable of innovation and problem-solving. This workforce need is particularly acute in high-demand areas such as microelectronics. Recent reports project that the U.S. semiconductor industry will face a substantial shortfall of skilled professionals by 2030, driven by increased global demand and policy initiatives such as the CHIPS and Science Act aimed at expanding domestic manufacturing capacity [1], [2]. Addressing this workforce challenge requires robust educational pathways that introduce students to related engineering tools early in their academic careers.

First-Year Engineering (FYE) programs play a critical role in this pipeline. These programs represent a formative period that influences student retention, the development of foundational technical skills, and the early formation of engineering identity and career interests [3], [4]. Well-designed FYE experiences aim to move beyond the simple delivery of content by fostering confidence, engagement, and a sense of relevance often through hands-on, technology-mediated learning experiences [5]. As a result, the selection and implementation of instructional technologies in FYE courses have become a consequential pedagogical decision rather than a neutral logistical choice.

Previous research on the integration of microelectronics into FYE course has routinely reported increases in student motivation and engagement, however significant challenges regarding scalability persist [6]. A recent study by our research group identified significant increases in students' awareness, motivation, and transformative experiences following their participation in a FYE curriculum that integrated hands-on microelectronics activities into existing engineering design curricula [7]. A subsequent qualitative inquiry expanded on these results, finding that while students generally enjoyed the integration of microelectronics, their engagement with the technology was heavily mediated by prior access disparities and the social dynamics of team-based learning [8].

While this previous investigation provided critical insights into the intervention's effects, the analysis was restricted to a single course section under a single instructor. This localized focus left questions regarding how the variability of instructional delivery across different environments might shape student outcomes. The current study serves as a critical expansion by examining microelectronics integration across multiple instructional teams and various course sections. Although we initially intended to analyze this broader population using the previously established codebook [8], the emergent student narratives revealed a persistent "thematic divergence" that required a revised analytical framework. Specifically, we identified a stark distinction in how students differentiate between their Technical Affect (reactions to tools) and their Instructional Affect (reactions to enactment).

Guided by Social Cognitive Career Theory (SCCT), this preliminary Work-in-Progress (WIP) paper investigates how the specific execution of a curriculum impacts student engagement, self-efficacy, and persistence intentions. By moving beyond the broader barriers of prior access and social dynamics identified in our previous work, we aim to uncover how the pedagogical "enactment" of the curriculum influences student outcomes. This investigation is guided by the following research question:

- How do first-year engineering students distinguish between their technological perceptions (e.g., self-efficacy, interest, and perceived utility of microelectronics tools) and their pedagogical perceptions regarding the instructional design and curricular integration of those tools?

By moving beyond the broad barriers of access and social dynamics identified in our previous work [8], we aim to uncover how the specific execution of the curriculum impacts student self-efficacy and future intent. Understanding this distinction is vital for scaling microelectronics education in large-enrollment courses where the instructional team's delivery may vary significantly across sections.

Research Design

This study is theoretically grounded in SCCT, a framework designed to explain how individuals develop career interests, make academic choices, and achieve persistence in their chosen fields [9]. SCCT posits that career-related behavior is the result of dynamic interactions between personal variables, environmental factors, and core cognitive constructs, such as self-efficacy expectations (beliefs in one's ability to perform specific tasks) and outcome expectations (beliefs regarding the consequences of those actions) [10]. In the context of engineering education, these constructs are shaped by learning experiences, which serve as the primary vehicle for developing the confidence and interest necessary for persistence.

While our previous work utilized SCCT as a deductive framework to identify how social dynamics and access disparities functioned as environmental barriers to engagement, the current study uses these constructs as a sensitizing lens to explore a more nuanced thematic divergence. We specifically focus on the Environmental Supports and Resources domain of SCCT, framing the "instructional team" and "pedagogical enactment" as critical environmental variables. By distinguishing between Technical Affect (the satisfaction and self-efficacy derived from the technology itself) and Instructional Affect (the environmental support provided by the curriculum's execution), we can identify how the delivery of a course influences a student's career-related perceptions independently of the technical tools employed. This expansion allows for a more comprehensive understanding of how multi-instructor implementation shapes the developmental pathways of first-year engineering students.

Description

ENGR 131 Ideas to Innovation 1 is an introductory first-year engineering course focused on data analytics, mathematical modeling, and engineering design. During the Fall 2023 term, the course enrolled over 2,000 students across 16 sections. Each section was supported by instructional teams consisting of a lead instructor, a graduate teaching assistant, and four undergraduate assistants. Students worked in teams of three or four. The curriculum featured three integrated microelectronics activities using Texas Instruments microcontrollers. During the activities, students engaged in hands-on prototyping and data collection to model complex systems such as smart greenhouses or proximity alarms. The activities were designed to bridge systems and computational thinking with modern engineering practice, thereby fostering early proficiency in technical problem-solving and automated design.

Participants

Participants were recruited from a single section of the subsequent course in the first-year engineering sequence. Following an in-class recruitment announcement, approximately 20 students expressed interest. Of those who signed up, a final sample of 17 students scheduled and completed the interview process. Each participant engaged in a semi-structured interview, with durations ranging from 10 to 30 minutes depending on the depth and detail of the responses provided. To acknowledge their time and contribution to the study, participants received a $20 cash incentive immediately following the completion of the interview. All participants were 18 years of age or older.

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

Data Collection – Semi-structured Interviews

This study utilized semi-structured interviews designed to elicit detailed accounts of student experiences with the integrated microelectronics curriculum. The semi-structured format allowed interviewers to ask follow-up questions, tailoring the discussion to the unique perspectives of each participant. By gathering these detailed reflections, the study produced rich, nuanced data that highlights how hands-on microelectronics activities influence both individual student perspectives and broader shared learning outcomes. This qualitative approach provided a flexible framework that prompted participants to reflect on their exposure to microelectronics prior to the course, their experience and expectations with the course, their evolving interest in the subject, and their plans for future engagement with microelectronics.

To ensure the interview protocol was robust, the research team employed a collaborative design process informed by SCCT literature and prior empirical findings. Key themes identified from an analysis of short-response survey questions served as the foundation for the interview prompts, allowing the researchers to dive deeper into previously identified student perspectives.

The interview protocol was structured around three thematic pillars: prior exposure to microelectronics and programming, attitudes during ENGR 131, and prospects for future engagement. The instrument consisted of 17 open-ended questions (e.g., “How did your interest in using microelectronics evolve over the semester?”), each supported by up to three follow-up prompts. The protocol underwent rigorous pilot testing with four course alumni to ensure alignment with the study’s research goals. These pilot sessions, combined with internal interviewer training, allowed the research team to refine the prompts for clarity and depth. This process guaranteed that the interviews would effectively capture meaningful data regarding the impact of microelectronics on student engagement, self-efficacy, and career trajectory. Interview recordings were transcribed using Rev AI, an AI-assisted transcription service. The research team performed a manual audit of each transcript before importing into NVivo, a qualitative data analysis software, for secure storage and systematic analysis.

Data Analysis

The data analysis followed an iterative, hybrid deductive-inductive approach. We began with the deductive application of the codebook developed in the previous study of this research; structured around SCCT constructs and thematic pattern codes. This established a conceptual baseline that allowed for a systematic exploration of how the microelectronics activities impacted students' perceptions of microelectronics and their outcome expectations. In contrast with the previous study, this study involved students who came from different sections of ENGR 131 with different instruction teams.

As coding progressed, a distinct pattern emerged that was not as prevalent in the previous study. While the first study found that interest and persistence with microelectronics remained consistent or increased throughout the course, the current data revealed a divergence of student sentiments. Specifically, we observed a consistent positive sentiment toward the microelectronics tools paired with a notable negative sentiment toward the course structure and the integration of those tools.

Because the existing codebook was not designed to capture this specific tension between tool engagement and pedagogical satisfaction, the research team adopted an emergent research design. We iteratively refined the codebook and realigned the research questions to specifically investigate how students differentiated between their perceptions of microelectronics as a tool versus their perceptions of the broader activity execution and learning outcomes. This shift facilitated a more granular examination of the factors that participants identified as influencing their engagement and persistence with microelectronics. Specifically, the shift highlighted how student perceptions of microelectronics diverged due to their experiences within the course structure. Following multiple rounds of iterative refinement and team consensus-building, we established a new comprehensive codebook to facilitate the thematic analysis (Table 1).

Table 1. New Pattern Codes

Category	Definition	Sub-Category
Supports & Barriers to Engagement	Statements identifying factors that either facilitated or hindered a student's ability to interact with microelectronics	External to course
		Internal to course
		Internal to self
Technical Affect	Expressions of the student’s emotional and psychological relationship with the **microelectronics** hardware and software itself	Self-Efficacy
		Perceived Utility
		Tool-Specific Satisfaction
Instructional Affect	Student reactions to the pedagogical execution and logistical "enactment" of the course	Activity Design
		Curricular Expectations
		Resource & Environment Satisfaction
Openness & Outcome Expectations	Statements reflecting the student's future-oriented trajectory and belief systems	Academic & Professional Openness
		Outcome Expectations
		Identity Alignment

Results & Discussion
Preliminary analysis of four semi-structured interviews reveals a distinct separation between students' Technical Affect (feelings toward microelectronics) and their Instructional Affect (perceptions of course enactment). In general, participants held positive views of microelectronics but expressed dissatisfaction with its pedagogical implementation.

Prior to course engagement, participants' Curricular Expectations varied widely, yet all participants maintained a baseline level of openness toward learning about and with microelectronics. For instance, Kai anticipated that microelectronics would provide a "more engineering" feel compared to software-only tools like Excel: "I thought it was preferable to doing stuff with them in Excel that would be more exciting and more feel almost more engineering I guess." Conversely, Dakota adopted a "neutral" stance, while Alex expressed initial pessimism based on past experiences, though they maintained a degree of Internal Self-Efficacy by believing they could succeed with peer support.

As the course progressed, a significant disconnect appeared regarding Activity Design and Pacing. Participants identified a "de-emphasis" of the technology, noting that activities were underutilized or disconnected from the rest of the course. Morgan described a sense of "disappointment" upon learning the hardware components were not a required part of the grade:

> "I was super excited. Texting my parents, actually. But then, kind of getting disappointed because it wasn't a required part of our class, which is super weird. So, I do not know how other sections did it, but our in-class activities were optional."

This lack of curricular emphasis acted as a Barrier to Engagement, further compounded by Pacing and Time Constraints. Kai noted that students were often "handed" kits without sufficient time or instructional guidance, leading to a sense of incompletion when tasks were left without a conclusion:

> "So actually, for the classroom activities, I felt like we were not giving enough time to really be able to complete them. I felt like, so I put this like some of the TA's and as well as the professor and the graduate TA as well kind of seemed like they didn't actually didn't know what they were doing in regards to it, so we were, we were kind of just handed them and then we were told to do something. And then, after that it just felt like they were unable to really help us. And we ran out of time there, so they were just like, OK well, that's it."

The participants highlighted a significant gap between the presence of the hardware and the depth of the instruction provided. Dakota expressed a desire for a deeper Task/Activity Design that moved beyond "copy and paste" code, wishing for more instruction on how to use microcontrollers "outside of class" for broader applications:

> "I don't think that class really taught much about it. It was more just like follow these instructions, copy and paste the code and it was cool how they worked. I just one thing I wish I would have known about coding more is like I know how to program like software. Little programs you know that it's like here's a number, Do something about it.

> You know. I don't actually know much about programming like hardware like you know. The little like microcontrollers that much which is something I wish I knew more about, more like computer engineering kind of thing, I guess. I wish there was actually like a bigger emphasis on actually teaching the coding for microelectronics.

This perceived lack of instructional depth resulted in a struggle to transfer knowledge. For example, Alex reported an inability to "translate anything from the TI kits to coding," signaling a breakdown in the internal course support system. This suggests that while curricular materials were present, the enactment did not provide the scaffolding necessary for students to build technical mastery.

Despite these instructional frustrations, most students maintained high Openness and Outcome Expectations. For Morgan, the presence of microelectronics encouraged them to "stick with electrical" engineering, as they began to see the hardware as a "practical" component of the "real world." Similarly, Kai expressed a desire for microelectronics to play a role in their future career, noting an interest in the semiconductor industry. Even Dakota, while primarily committed to mechanical engineering, viewed computer or electrical engineering as a viable "second choice" because the combination of software and hardware was inherently "interesting." This indicates that the appreciation for the tool itself remained resilient and even grew for some participants despite their negative Instructional Affect.

Conclusion

In summary, this preliminary analysis reveals a thematic divergence where, in our sample, students' Technical Affect remains resiliently positive while their Instructional Affect is impacted by frustrations with the course enactment. While the participants recognized the value of microelectronics tools, instructional design constraints like optional grading and rushed pacing often served as a primary barrier to deep engagement.

Furthermore, this preliminary analysis identified a larger variance in student responses compared to the previous study. This variance was attributed to the difference in class section, as the Instructional Team acts as a pivotal variable in the learning experience. While some participants maintained high academic openness despite challenges, others felt their progress was hindered by a lack of consistent expertise and support from teaching assistants and instructors.

Limitations

The preliminary nature of this work-in-progress is limited by the analysis of only four out of seventeen interviews. While the protocol touched on curriculum, its primary focus on the personal impact of microelectronics may have restricted the depth of findings regarding specific pedagogical enactment. Finally, the qualitative interpretation of these student narratives is inherently influenced by the researchers' subjective perspectives.

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