Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #47593

Title: Building Curiosity and Competency: Designing and Evaluating Activities for Microelectronics Education (Evaluation of Program/Curricula)

Yash Ajay Garje, Purdue University at West Lafayette (COE)

Yash is a Ph.D. student at the School of Engineering Education at Purdue University. His research aims at broadening student participation in STEM through robotics education. His research focuses on enhancing STEM participation through robotics education, employing learning technologies and storytelling to craft inclusive educational experiences that foster student belonging.

Shauna Adams, Purdue University at West Lafayette (COE)

Shauna is currently a PhD student in Engineering Education at Purdue University. She previously worked for 10 years as a Systems Surety Engineer and 15 years as a coordinator/advisor of various pre-college engineering programs. Shauna earned her BS in Mechanical Engineering from North Carolina Agricultural and Technical State University and her MS in Mechanical Engineering from The Ohio State University. Her research interest includes understanding the impact of community-based engineering programs on student major choice for underrepresented groups in engineering, with a specific focus on Black/African American youth and inclusive program evaluation methods. Shauna is engaged in Purdue's Engineering Education Graduate Student Association and Black Graduate Student Association.

Mr. Bruce Wellman, Purdue University at West Lafayette (COE)

Bruce Wellman is a National Board Certified Teacher (NBCT, Chemistry) who taught high school chemistry and engineering for 22 years. He is currently a doctoral student in the Engineering Education Department at Purdue University

Dr. Morgan M Hynes, Purdue University at West Lafayette (COE)

Dr. Morgan Hynes is an Associate Professor in the School of Engineering Education at Purdue University and Director of the FACE Lab research group at Purdue. In his research, Hynes explores the use of engineering to integrate academic subjects in K-12 cla

Building Curiosity and Competency: Designing and Evaluating Activities for Microelectronics Education (Evaluation)

Introduction

The U.S. share of global semiconductor manufacturing has declined from 37% in 1990 to just 12% today, largely due to outsourcing to Asia [1], [2]. The COVID-19 pandemic exposed critical vulnerabilities in the global chip supply chain. In response, the CHIPS Act of 2022 was passed to reduce U.S. dependency on foreign semiconductor supply chains and address vulnerabilities in the industry. To safeguard the economy and national security, the act has spurred major investments in semiconductor manufacturing, design, and research, including new and expanded fabs in Arizona, Texas, Ohio, New York, and Idaho [3]. These investments underscore the urgent need for a competent workforce.

McKinsey projects that by 2030, the U.S. semiconductor industry will require 300,000 additional engineers and 90,000 skilled technicians. According to reports by the National Science Board [4] and the Committee on STEM Education National Science and Technology Council [5], the U.S. faces a significant shortage of STEM majors and graduates. With STEM occupations projected to grow [6], there is a pressing need to broaden participation in STEM fields, with particular emphasis on exposing students to the niche areas of semiconductors and microelectronics.

Opportunities with Informal Education

The need to grow the US share of semiconductor manufacturing highlights the need for robust, resource-rich educational programs that expose students to the semiconductor and microelectronics fields. While formal education platforms and programs exist, they often remain relatively inaccessible to many students, especially those who are still deciding whether to pursue careers in STEM and are constrained by restrictive standards and coursework that has little room for such new content. This makes informal education avenues essential for attracting and retaining an interest in STEM, especially semiconductors [7]. According to [8], informal education provides students with opportunities to participate, practice, and feel a sense of belonging in the STEM ecosystem, positioning them well for making informed career decisions. Research [9], [10], [11] supports the idea that informal education increases the likelihood of students pursuing STEM careers. The National Research Council [12] emphasizes the need to broaden women's and minorities' participation in STEM and that informal education can serve as an effective launchpad for this goal.

Problem/Gap:

The semiconductor industry is experiencing unprecedented growth, driving the need for a skilled and diverse workforce. However, high school students who are on the brink of making critical career decisions face significant challenges in accessing structured, comprehensive programs that could help them make informed choices about pursuing careers in semiconductors and microelectronics.

Challenges based on the literature review:

Our literature survey focused on identifying potential hindrances to developing a competent workforce for the future. We identified four prominent challenges that make choosing a career in semiconductors and microelectronics particularly challenging for the youth. First, there is a **lack of exposure** to the semiconductor ecosystem and its multidisciplinary nature, which deters students with diverse interests and strengths from envisioning their place in the field [13]. Second, **lack of awareness** about cutting-edge research and the type of work that goes on in industrial facilities discourage the youth from immersing themselves and examining their fit [14], [15]. Third, there are **limited opportunities** to develop hands-on skills essential for thriving in semiconductor-related environments [16]. Finally, **inaccessibility** to resources, mentors, and counseling regarding potential career pathways in the continuously evolving industry raises the barriers to entry into the field [17]. These challenges motivated us to design a program that helps youth make more informed career decisions.

Context:

We developed a two-week-long paid ($1500 stipend) summer program for rising high school juniors and seniors interested in learning about the semiconductor and microelectronics industry. This program is a collaborative effort of a large public Midwestern University and a local community college and is supported through a regional economic development initiative. One of the many goals of the grant is to develop a competent workforce for the rising semiconductor industry and boost the economy of the region. To tackle the challenges found in the literature and develop a competent workforce for the industry, we designed this program with three primary intentions:

- Raising **awareness** about the social and technical relevance of the industry.
- Providing **immersive opportunities** to **explore** careers and educational pathways in the field that align with students' interests and ambitions
- Building the **technical - nontechnical skills** and **motivation** to pursue careers in the semiconductor and microelectronics field.

These intentions were complemented with the following learning objectives where participants would:

- Use the fundamentals of electronics to develop simple paper circuits
- Interpret and develop simple Scratch codes to operate microcontrollers (BBC micro:bits)
- Map the diverse stakeholders and get a big-picture view of the Semiconductor Ecosystem
- Identifying potential career opportunities in the ecosystem (academia and/or industry) that seem attractive and align with personal interests and values.

Bridging the Gap:

Through our program, we intend to provide a structured, holistic approach that combines exposure, skill-building, research immersion, and mentorship. This paper demonstrates evidence of five types of value—**experience, skill development, factual knowledge, awareness, and emotional engagement**—that we intend participants to gain through the program. With these learnings, we believe students are more likely to make well-informed decisions about their future careers in semiconductors and microelectronics.

Participants:

We invited eligible applications from rural schools across six counties near the public university as per the requirements of the funding agency. However, due to the daily commuting requirements to the university and community college, our applicant pool was concentrated in the home county of the university. We recruited sixty high school participants from diverse backgrounds who committed to truly immerse themselves in the experience.

Methods

Program Design:

In the two weeks of the program, we aimed to immerse the participants in the academic and industrial world of semiconductors and microelectronics. We provided participants with an opportunity to experience learning at a community college and a large public university and took them on industrial visits to see semiconductor technologies being applied to real-world products. The program is built with four sequential modules and a set of unique activities that give participants a combination of theoretical and practical exposure, and a supplementary hands-on skill-building experience.

The first module provides an overview of the field and how semiconductors impact our daily lives. The second module introduces participants to the planning and procurement efforts needed to keep the global industry working. The third module focuses on the manufacturing processes involved in making semiconductor devices and takes participants to high-tech industrial and research facility tours. Finally, the fourth module focuses on showing the big network of stakeholders in the field and emphasizing the complex lifecycle of the semiconductor products. Table 1 briefly describes the activities from each of the four modules.

After completion of all these modules, participants put together their learnings by working on a design project where they develop a proof of concept to address one of the 17 sustainable development goals suggested by the UN. The catch in these design projects is that the participants must highlight the impact of semiconductors on their proposed solutions.

Activity Name	Description
Activity 1: Introduction to Circuits	This was a low-barrier activity designed to build confidence among the participants through familiar tasks like lighting LEDs, assembling 2D and 3D puzzles, and making paper circuits. The activity introduced the fundamentals of circuitry and microcontrollers.
Activity 2: Micro:bit Microcontrollers	This activity familiarized participants with the different input and output capabilities of a BBC micro:bit microcontrollers. The stations allowed participants to engage with the microelectronics hardware, explore and interpret the underlying Scratch code and witness it's real-time feedback.
Activity 3: Mapping the Semiconductor Ecosystem	This activity introduced the participants to a socio-technical lens to view technology. Participants develop stakeholder maps and product lifecycle assessments for familiar electronics like smartphones, toasters, and cars.
Activity 4: Mining and Core-Cutting Simulation	Here, participants simulated core-cutting in mining using a hands-on approach with plastic straws and coffee cakes to predict internal layers. This novel, geology-themed activity spiked awareness as participants learned about geological sampling and interpretation. This activity was originally developed by Bonnie Magura, Jackson Middle School, Portland, OR and we integrated this activity in our program [18].
Activity 5: Cookie Mining activity	Here, participants worked in teams to mine chocolate chips from cookies using household items like toothpicks and paper clips. This activity simulated the process of mining and presented participants with the basic economics behind resource extraction and brought their attention to the environmental impact of mining and extraction. We adopted this activity from *[19]*.
Activity 6: Semiconductor Jeopardy Game	This was a Kahoot game focused on industry facts, geopolitical insights and trivia about the semiconductor sector.
Activity 7: Poster Making and Storytelling on Semiconductor lifecycle	Here participants researched how the semiconductor industry can help address the UN Sustainable Development Goal defined in the [20] report. Participants created posters and narratives around sustainable electronics consumption and reuse.

Table 1 Summary of the seven activities of the summer program

Research Design:

All the above activities were conducted at the public university on different days during the two-week program. In this paper, we aim to study participants' engagement during the above-mentioned seven activities and investigate two research questions:

1. How did the participants engage with the seven activities?
2. How does this engagement align with the program designers' engineering workforce development intentions?

As a part of the summer program, participants produced multiple forms of reflection that generated insights into the program's design and impact, and recommendations for future improvement. These reflections included pre and post-surveys, daily reflections, post-activity reflections, and focus group discussions.

Our research questions focus on investigating participant engagement and learning experiences from the program activities. Hence, post-activity reflections are a suitable choice to use for this study. Since there are multiple ways to engage and draw from a single activity, we adopt a basic qualitative research design approach and photovoice as an investigation method to conduct research. This method allows for flexible and in-depth portrayal of participants' perspectives and experiences throughout the activity [21], [22]. These photovoice reflections allow us to understand the various ways in which the activity resonated with the participants, and these reflections also serve as a reality check for designers to validate the design intent of the activity.

Data Collection:

The post-activity reflection was a two-fold process. First, while the participants engaged in the activity, we instructed them to capture photographs of interesting moments using their smartphones. Second, after completion of the activity, we asked participants to select and submit only one photograph, along with a caption justifying the selection and/or describing the moment they had captured in the photograph.

We collected these reflections using a Google Form for all activities. The project had an IRB approval, and only reflections from the 53 consenting/assenting participants were used for research purposes. Table 2 shows an example of a post-activity reflection submitted by a participant after interacting with the BBC mirco:bit microcontroller.

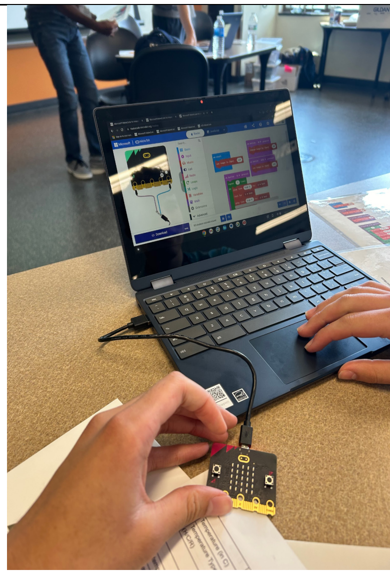
Photograph	Caption submitted by the participant
	The activity with programming a song onto a microchip was really fun. We worked with the group behind us to continue the song “Runaway” by Kanye. I learned a lot about how programming notes into a speaker works, and it is a lot of trial-and-error finding what sounds right. It was definitely my favorite part so far.

Table 2 Sample reflection: Photograph and caption

Data Analysis:

To answer the first research question, we use thematic analysis, a qualitative analysis technique that allows us to systematically identify, analyze, and report themes within the research data. In our case, we use a five-step approach to thematic analysis suggested by [23] to analyze the post-activity reflection data. First, we familiarized ourselves with the data and observed the variety of Photovoice reflections. During this step, we also filter out data from participants who do not consent to the research and those who misplaced or turned in wrong submissions. Second, we revisit the data and note similarities and differences in participant reflections. Here, we form the first set of themes or ideas that emerge from the data. Third, we revisit the data, but this time, intending to verify if the data is well represented through the noted themes and, if required, modify and update the themes as per the new observations. Fourth, we clustered common themes and named them to arrive at five core themes. Fifth, we report the themes and their description to answer the first research question substantially.

To answer the second research question, we analyze the reflections from each activity and count the frequency of themes identified in the earlier exercise. The frequency analysis of the themes provides insights in two aspects: first, it helps us understand the overall essence captured by the participants in each activity and how these activities contribute to their understanding of the semiconductor industry. Second, it allows us to compare the type of engagement across all the activities and understand whether the program as a whole offers a balanced form of engagement to the students.

While the first research question explores the varied ways participants individually engaged with the activities, the second research question highlights broader patterns in how specific activities were received. By integrating these perspectives, the research questions and methods offer a comprehensive view of the program’s impact.

Table 3 illustrates that, out of sixty participants, only a subset of reflections was analyzed due to the exclusion of erroneous submissions and entries from non-consented participants.

	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7
Number of usable reflections	48	49	50	51	42	39	43

Table 3 Reflection counts across activities

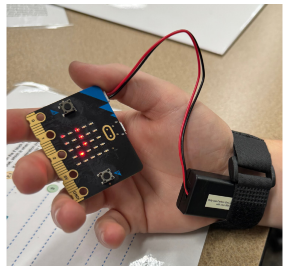
Findings

Table 4 shares some photographs submitted by the participants in each activity. Even though the photographs showed a very limited variation, the captions that came along with the photographs brought out the diversity and uniqueness of experiences that each participant drew from the activities. An important aspect that we highlight in this research is, that even though all participants engaged with the same activities, they resonated with different aspects of these activities and drew different learnings from the experience. The photovoice method allows us to precisely capture the richness of these different perspectives.

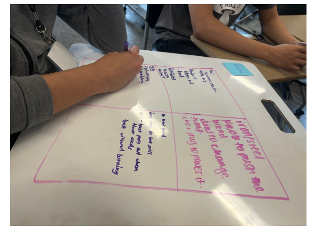
Insights on engagement from participant reflections:

This section presents the set of five themes that we noticed from the participants' captions across all activities. We noticed that memorable takeaways were related to experiences, emotional engagements, skill learning, knowledge or factual gain, and awareness about topics related to the semiconductor industry. Table 5 presents a brief description of the theme and illustrates it with a sample reflection from the participants.

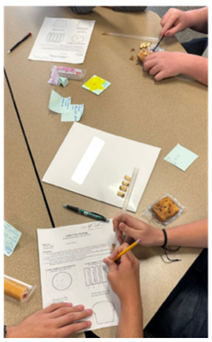
Participant lighting up an LED from Activity 1
Photograph (a)



Participant operating the BBC micro:bit from Activity 2
Photograph (b)



A team making a stakeholder map from Activity 3
Photograph (c)



A team filling up the worksheet from Activity 4
Photograph (d)

A participant engaged in Activity 5
Photograph (e)

A participant submitted the photo of the reward for Activity 6
Photograph (f)

A team engrossed in preparing a poster for Activity 7
Photograph (g)

A poster created by one of the teams during Activity 7
Photograph (h)

Table 4 Thematic representation of photographs submitted across activities

Theme Name	**Description**	**Reflection caption**
Experience	This theme recognizes cognitive engagement noticed in the reflections. It includes moments where participants encounter novelty, face challenges, or achieve milestones, reflecting the value and memorability of their participation.	This photo is interesting because it involved a 3D puzzle of a lion and required higher levels of spatial reasoning to solve the puzzle. I took the photo because it was the finished product of our team's work.
Emotion	This theme capture the internal, affective, and emotional reactions the participants externalized in their responses after engaging in learning activities. These emotions reveal participants' levels of interest, surprise, enjoyment, pride, frustration, or curiosity, offering insights into how activities resonate on an emotional level.	I very much enjoy music and producing music, so I found it very interesting that we were able to code music into the chips and make it play. We were so mesmerized by the LEDs! It's an incredible culmination of electrical engineering that we appreciate!"
Skills	This theme identifies competencies that participants develop/ apply/ exhibit during the program's activities. These include tangible skills like note-taking, teamwork, circuit diagramming, and coding, as well as more abstract competencies like strategic thinking, problem-solving, reasoning, and effective communication.	This code was a struggle to read and find out what some of it meant. I was able to learn more about it though by making changes to the code and seeing how it changed the output. I also found it interesting how the code can be different because of the designer of the output device. The extraction process involves many factors such as mining costs and equipment. The activity was interesting because it modelled the complex process of extracting materials from the Earth.
Factual knowledge	This theme identifies instances where participants demonstrate a clear grasp of technical information, a concept, or terminology introduced during the activity. This includes specific references to scientific and technical concepts such as circuits, batteries, LEDs, microcontrollers,	This Micro:bit involved a magnetic sensor that could detect magnetic forces. This activity was interesting because we experimented with the penetrating power of the sensor. I chose to take this photo because this [mining] activity allowed us to practice

	coding syntax, and industry-specific terms.	optimization of efficiency with regards to use of our resources.
Awareness	This theme identifies reflections where participants connect factual knowledge with broader socio-technical or environmental contexts. This awareness may manifest through realizations about the impacts, processes, or ethical considerations inherent in the field.	I chose this photo because it shows the very beginning of the process for making almost anything [core cutting] as it goes from finding minerals to the product. It was interesting to see how much it [mineral extraction] impacted the area when we mined.

Table 5 Themes and sample reflection from the participants

These five themes show how participants engaged with the summer program activities. It leads us to inquire about the alignment of these engagements with that of the program designers' engineering workforce development intentions.

Aligning engagement with workforce development goals:

To investigate the second research question, we adopt a frequency analysis approach to evaluate participant reflections across all activities. This approach allows us to gauge the collective impact generated by each activity and then compare it with the designers' intent. We follow the following three steps:

- First, we count the occurrences of the five themes (that we derived above), in the reflections from all the seven activities. It is not uncommon to notice multiple themes show up in a single reflection, and for such cases, we assign all the applicable themes to the reflection.
- Second, we tally these occurrences to gauge the performance of each activity in terms of the five engagements and comment on the alignment with the designers' intent.
- Third, we compare the performance activities with each other and discuss the combined impact of the activities.

Table 6 presents the percentage contributions of each theme across all activities

Activity →	1	2	3	4	5	6	7	Mean	Std. Dev.
Total reflections	48	49	50	51	42	39	43	46	-
Total Codes % (count)	100% (113)	100% (124)	100% (136)	100% (120)	100% (99)	100% (61)	100% (98)	- -	-
Experience	32% (36)	28% (35)	21% (29)	28% (34)	31% (31)	49% (30)	35% (34)	32%	0.0861
Emotions	22% (25)	23% (28)	18% (25)	23% (37)	21% (21)	33% (20)	21% (21)	23%	0.0455
Skills	26% (29)	20% (25)	19% (26)	19% (23)	16% (16)	5% (3)	28% (27)	19%	0.0736
Factual Knowledge	7% (8)	15% (19)	27% (37)	8% (10)	11% (11)	3% (2)	8% (8)	11%	0.0785
Awareness	13% (15)	14% (17)	14% (19)	22% (26)	20% (20)	10% (6)	8% (8)	14%	0.0497

Table 6 Percentage contributions of each theme across activities.

The first column of the table shows the tally of code for the first activity – i.e., Introduction to Circuits. We observe that the Experiences, Emotions, and Skills contributed 32%, 22%, and 26% of the total codes (113) used in the activity, respectively. On the contrary, the codes for Factual knowledge and Awareness only contributed to 7% and 13% of the total codes, respectively. We can infer that this activity was successful in delivering a rich and engaging experience to the participants but did not come across as an activity that built participants' know-how regarding the semiconductor industry.

To further illustrate these findings and analyze the alignment between engagements and designers' intentions, we re-present Table 6 in the form of Figure 1 to visually convey the distribution of engagement within and across each activity. The representations in Figure 1 allow us to observe the evolution of engagement styles as the program progresses. Figure 1h shows a holistic impact of all the activities together and provides a check on how the participants received the overall summer program.

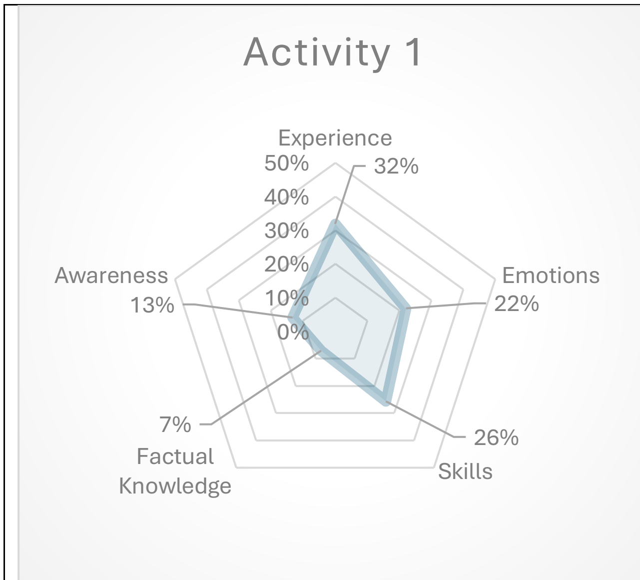


Figure 1a

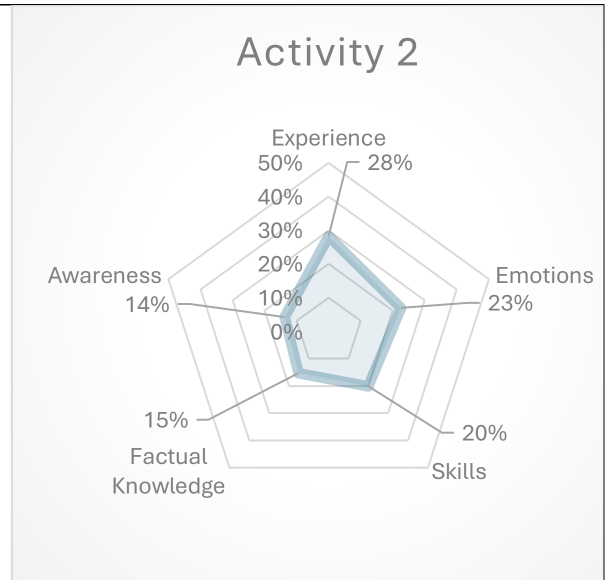


Figure 1b

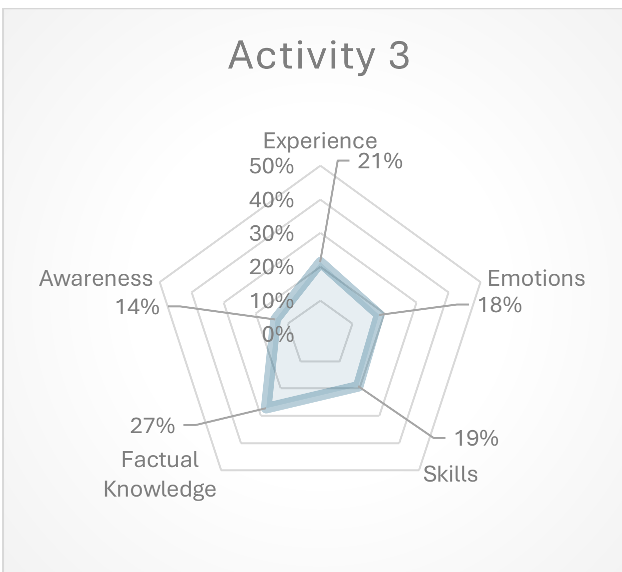


Figure 1c

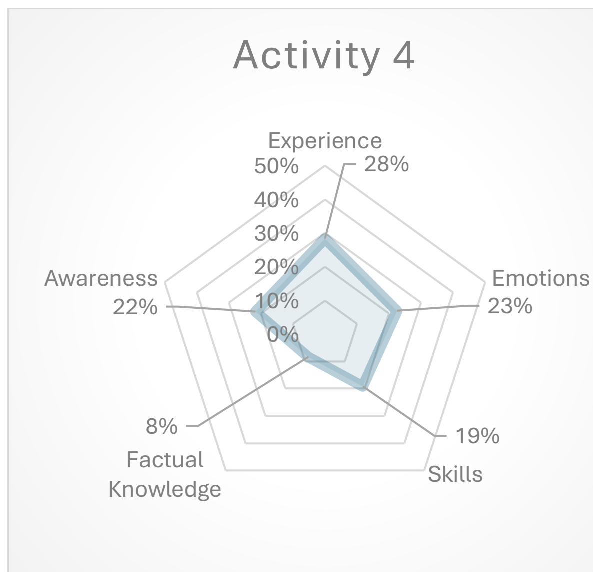


Figure 1d

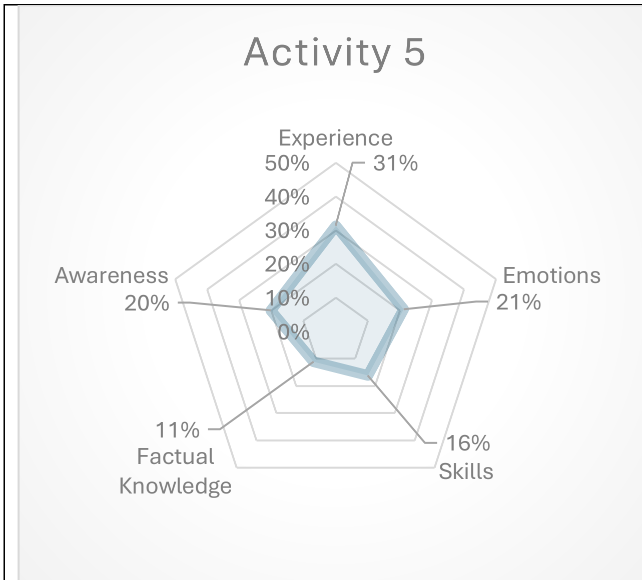


Figure 1e

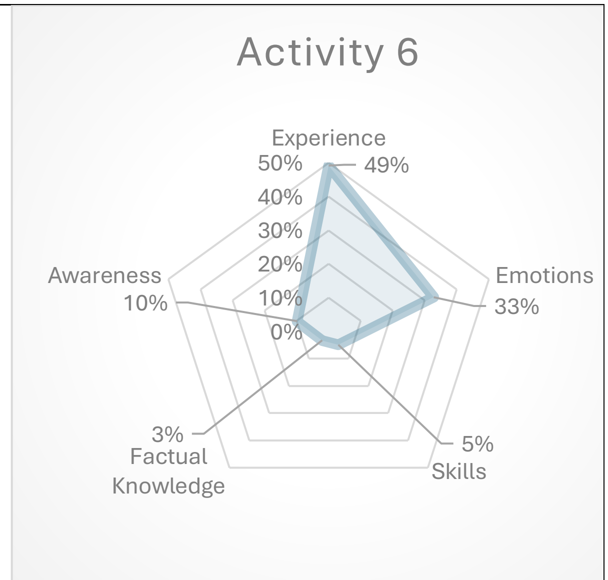


Figure 1f

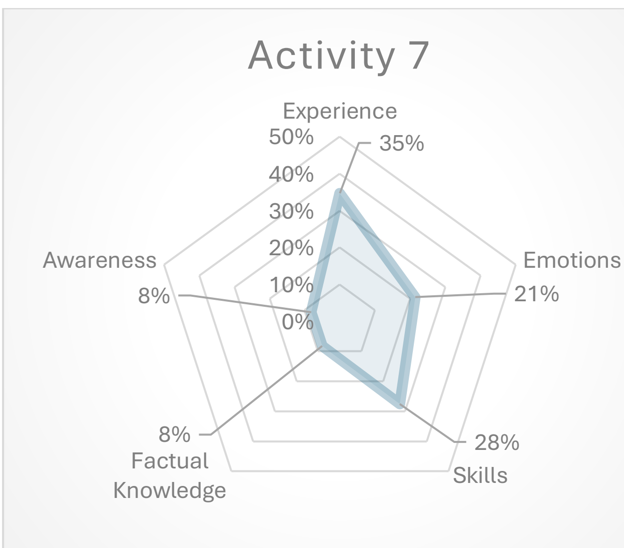


Figure 1g

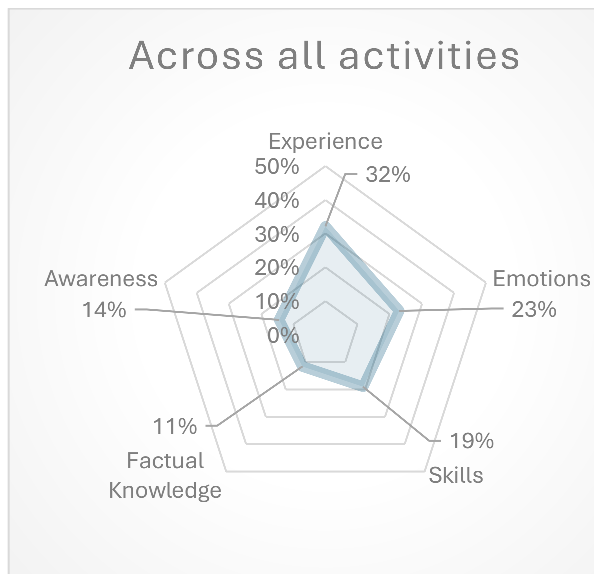


Figure 1h

Figure 1 Visualizing the spread of activities across the five themes

Ideally, a very evenly balanced program covering all the program design intentions would indicate a 20% contribution towards all five learning intentions. Figure 1h shows the real impression of the summer program on the participants, and we can notice that 31% of students' reflections resonated with the experience that was offered at the program. 23% and 19% of the reflections indicated emotional engagement and skill building, respectively. Finally, 14% of the activity reflections recognized gains in awareness about the semiconductor industry, and 11% of reflections highlighted factual knowledge learning.

The program designers' (our) intentions followed a Socio-Cognitive Career Theory (SCCT) model where we wanted to create a learning experience where participants could connect their current knowledge, interests, and experiences to the semiconductor industry. The intention for these connections was to allow students to explore their interests in the field, develop new goals, and take actions consistent with fulfilling those goals in pursuit of a career in the industry.

Discussion

We infer that the participants showed experiential and emotional engagements to be the memorable takeaways of the summer program. Further observations reveal that participants took advantage of the multiple inclusive pathways of engagement embedded in the activities, which gave way to multidisciplinary skills being seen and recognized. Teamwork and collaborative efforts have been the backbone of the experience but never overpowered the component of individual development and allowed for a balanced and holistic exposure to the field. In this section, we dive into these topics in further detail and discuss how our program design and participant reflections follow the topics of self-efficacy, outcome expectations, and learning experience discussed in the Socio-Cognitive Career Theory.

Creating Inclusive Pathways to Experiential and Emotional Engagement:

Echoing the work of [24], [25] the first findings from our work suggests that hands-on, self-exploratory, and gamified activities were particularly memorable and impactful for participants. The intentional design of the program offered multiple avenues for engagement, ensuring participants from diverse backgrounds and with varied interests could find meaningful ways to contribute. We noted three methods for creating inclusive pathways:

Leveraging Personal Talents: Activities such as programming the BBC micro:bit exemplified how participants connect their unique talents with technical skills. For instance, one participating team, inspired by their passion for music, created a program that played melodies on the BBC micro:bit. They described the experience as meaningful, expressing joy in merging their interests with the technology.

Collaborative and Accessible Experiences: Activities like the mining activity used simple tools like cakes and straws and easy tasks like mining chocolate chips to eliminate barriers to participation. This ensured that no prior knowledge was necessary and allowed participants to work in teams, discuss strategies, and appreciate healthy competition, which made the experience memorable and meaningful.

Highlighting Multidisciplinary Skills: With activities like system mapping, participants with artistic or storytelling skills felt like leading, creating visually engaging posters, and narrating stories about the semiconductor ecosystem. Participants could see how their skills—whether technical, artistic, or communicative—were integral to the field.

This variety in engagement pathways created an environment where participants felt seen, appreciated, and capable of succeeding in the program.

Reflection on Activity Design and Learning Balance

The findings from the frequency analysis demonstrate the alignment of participant engagement with designers' intent of workforce development. Figure 1 suggests that an ideal activity would balance all five themes—experience, emotional engagement, skills, factual knowledge, and awareness. However, as activities serve specific developmental purposes, this balance is not always achievable or necessary. Introductory activities prioritized emotional and experiential engagement to ease participants into the program and build a sense of familiarity, as seen in Activities 1 and 2. Mid-program activities leaned towards awareness and factual knowledge, preparing participants for more technical content while maintaining engagement. Towards the end, activities like the *cookie mining activity* and *poster creation* balanced real-world experience with curiosity and practical knowledge. Overall, this developmental progression supported diverse learning objectives, equipping participants with the skills, knowledge, and awareness needed to choose a career and engage deeply with the semiconductor industry.

Connections to the Socio-Cognitive Career Theory

Socio-cognitive career theory (SCCT) provides a robust framework for aligning the program's workforce development goals with the needs of the participants (i.e., to make an informed career choice). The framework facilitates addressing three crucial topics that mirror our motivation for the program design – the development of the academic and career interests among students, providing a conducive environment for knowing their educational and career choices, and preparing them to succeed in their academic and career endeavors. Building on the work of [26], SCCT can provide clear pathways for designing interventions that shape career trajectories. [26] suggest three models – interest, choice, and performance models that inform career choices. In the following sections, we discuss how these models connect with our larger goal of workforce development.

Developing academic and career interests among students:

The interest model by [26] posits that self-efficacy—built through accomplishments, experiences, social persuasion, emotional states, and outcome expectations—contributes to the development of career interests. Furthermore, self-efficacy improves with exposure, practice, and feedback, which, in turn, foster expectations about the positive outcomes of career-related engagements [27], [28], [29]. In alignment with this model, our camp activities were designed to create hands-on experiences that build competence. These experiences allowed students to expect and envision successful outcomes, ultimately nurturing their interest in the semiconductor field.

Building on this foundation, self-efficacy plays a crucial role in fostering participants' belief in their ability to engage with challenging material [28]. To address this, the program incorporated activities that bolstered self-efficacy by offering hands-on opportunities where participants could apply and practice new skills. For instance, coding with BBC micro:bits exemplified the program's approach by combining theoretical background with practical experience. This integration allowed participants to see firsthand what they were capable of achieving. Consequently, this practical application not only reinforced their skills but also built a sense of competence and familiarity with microelectronics.

Creating a conducive environment for educational and career choices

The choice model from SCCT highlights that while self-efficacy and outcome expectations play pivotal roles in career decisions, environmental and social influences also hold significant sway. Factors such as family pressures or economic considerations often override personal interests [26]. Recognizing these challenges, our program intentionally creates an environment where students are encouraged to explore their genuine interests while receiving support to navigate external influences.

Outcome expectations, which focus on understanding the practical implications of pursuing a career, were addressed through exposure to professionals, industry environments, and academic spaces. This "show, don't tell" approach allowed participants to see real-world examples of where their skills could lead, establishing realistic expectations about their future trajectories. The *awareness* theme played a critical role here, capturing moments when participants began to understand how their skills and knowledge fit into the broader industry context. Reflections indicating participants' connections between learning and real-world outcomes revealed their emerging clarity about what a career in semiconductors might entail.

Finally, the *experience* and *factual knowledge* themes further supported outcome expectations by demonstrating concrete learning milestones achieved within the program. Recognizing these achievements gave participants confidence that they were beginning to develop the competencies necessary to succeed in the field. This realization helped them see the relevance of their skills and how these could be applied in a professional setting, thereby solidifying their belief in their potential career pathways.

Preparing them to succeed in their academic and career endeavors:

The performance model of SCCT highlights the intertwined roles of ability and motivation in achieving success [26]. According to this model, higher self-efficacy and positive outcome expectations enhance motivation, increasing the likelihood that students will persist in their chosen fields. However, developing self-efficacy and, as a result, motivation requires a deliberate focus on creating meaningful learning experiences.

Learning experiences, as defined by SCCT, serve as one of the three foundations upon which participants explore and connect with new knowledge and skills [30]. The summer program provided a rich, diverse learning environment featuring a mix of activities, industry exposure, and practical applications. By engaging with factual knowledge—such as specific terminologies, processes, and foundational concepts—the program enabled participants to gain a clearer understanding of what the semiconductor field entails. Beyond factual knowledge, the awareness theme captured participants' moments of realization, where they began to understand the interconnectedness of stakeholders and the broader sociotechnical implications of the semiconductor industry.

This well-rounded learning experience not only exposed participants to various career pathways but also allowed them to identify which aspects of the field resonated most with their interests. Such exploration is critical, as it provides the knowledge base and experiential foundation needed to make informed and confident career decisions.

Conclusion

In conclusion, **emotions** spark engagement and influence the desire to continue learning. They work as one of the indicators to gauge whether a learning environment is working in favor of or against the intended learning objective. Themes of **Experience** and **skill** reflect active participation, skill-building, and, ultimately, growth in self-efficacy. **Factual knowledge** and **awareness** together deepen participants' understanding of both the technical aspects and broader societal impacts, aligning with clear learning experiences and outcome expectations. By monitoring participant reflections through these themes, we gained nuanced insights into participants' journeys through the program, allowing adjustments to foster greater self-efficacy, reinforce the richness of learning experiences, and clarify outcome expectations.

References:

[1] K. Bartlett, O. Burkacky, L. Li, R. Vrijen, and B. Wiseman, "A roadmap for US semiconductor fab construction," McKinsey and Company, Jan. 2023. Accessed: Jan. 12, 2025. [Online]. Available: https://www.mckinsey.com/industries/industrials-and-electronics/our-insights/semiconductor-fabs-construction-challenges-in-the-united-states#/

[2] US GAO, "Semiconductor Supply Chain: Policy Considerations from Selected Experts for Reducing Risks and Mitigating Shortages," U. S. Government Accountability, GAO-22-105923, Jul. 2022. Accessed: Jan. 12, 2025. [Online]. Available: https://www.gao.gov/products/gao-22-105923

[3] J. Badlam, S. Clark, S. Gajendragadkar, A. Kumar, S. O'Rourke, and D. Swartz, "What is the CHIPS and Science Act?," McKinsey and Company, Oct. 2022. Accessed: Jan. 12, 2025. [Online]. Available: https://www.mckinsey.com/industries/public-sector/our-insights/the-chips-and-science-act-heres-whats-in-it

[4] National Science Board, "Science and Engineering Indicators 2016," National Science Foundation, Arlington, VA, NSB-2016-1, 2016.

[5] The Committee on STEM Education National Science and Technology Council, "Federal Science, Technology, Engineering, and Mathematics (STEM) Education. 5-Year Strategic Plan.," Executive Office of the President, Washington, DC. National Science and Technology Council., PB2013108885, 2013. Accessed: Jan. 12, 2025. [Online]. Available: https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2013108885.xhtml

[6] D. Langdon, G. McKittrick, D. Beede, B. Khan, and M. Doms, "STEM: Good Jobs Now and for the Future. ESA Issue Brief #03-11," US Department of Commerce, Jul. 2011. Accessed: Jan. 12, 2025. [Online]. Available: https://eric.ed.gov/?id=ED522129

[7] T. Roberts *et al.*, "Students' perceptions of STEM learning after participating in a summer informal learning experience," *Int. J. STEM Educ.*, vol. 5, no. 1, p. 35, Sep. 2018, doi: 10.1186/s40594-018-0133-4.

[8] K. O'Connell, B. Keys, and M. Storksdieck, "Taking Stock of Oregon STEM Hubs: Accomplishments and Challenges: An Evaluation Report Prepared for the Oregon Chief Education Office," Oregon State University. Center for Research on Lifelong STEM Learning, Oregon, 2017.

[9] J. A. Kitchen, G. Sonnert, and P. M. Sadler, "The impact of college- and university-run high school summer programs on students' end of high school STEM career aspirations," *Sci. Educ.*, vol. 102, no. 3, pp. 529–547, 2018, doi: 10.1002/sce.21332.
[10] X. Kong, K. P. Dabney, and R. H. Tai, "The Association between Science Summer Camps and Career Interest in Science and Engineering," *Int. J. Sci. Educ. Part B Commun. Public Engagem.*, vol. 4, no. 1, pp. 54–65, Jan. 2014, doi: 10.1080/21548455.2012.760856.
[11] M. J. Mohr-Schroeder *et al.*, "Developing Middle School Students' Interests in STEM via Summer Learning Experiences: See Blue STEM Camp," *Sch. Sci. Math.*, vol. 114, no. 6, pp. 291–301, Oct. 2014, doi: 10.1111/ssm.12079.
[12] National Reseach Council, *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Washington, D.C.: National Academies Press, 2011. doi: 10.17226/13158.
[13] I. Obembe *et al.*, "Survey of Courses on Semiconductor Manufacturing at U.S. Universities," *IISE Annu. Conf. Proc.*, pp. 1–6, 2024, doi: 10.21872/2024IISE_7253.
[14] S. Murphy, A. MacDonald, C. A. Wang, and L. Danaia, "Towards an Understanding of STEM Engagement: a Review of the Literature on Motivation and Academic Emotions," *Can. J. Sci. Math. Technol. Educ.*, vol. 19, no. 3, pp. 304–320, Sep. 2019, doi: 10.1007/s42330-019-00054-w.
[15] L. T. O'Brien, A. Hitti, E. Shaffer, A. R. V. Camp, D. Henry, and P. N. Gilbert, "Improving Girls' Sense of Fit in Science: Increasing the Impact of Role Models," *Soc. Psychol. Personal. Sci.*, vol. 8, no. 3, pp. 301–309, Apr. 2017, doi: 10.1177/1948550616671997.
[16] C. J. Cappelli, K. L. Boice, and M. Alemdar, "Evaluating University-Based Summer STEM Programs: Challenges, Successes, and Lessons Learned," *J. STEM Outreach*, vol. 2, no. 1, 2019, Accessed: Oct. 27, 2024. [Online]. Available: https://eric.ed.gov/?id=EJ1418913
[17] M. Guthaus *et al.*, "NSF Integrated Circuit Research, Education and Workforce Development Workshop Final Report," Nov. 03, 2023, *arXiv*: arXiv:2311.02055. doi: 10.48550/arXiv.2311.02055.
[18] B. Magura, "Cupcake Geology: Interpreting Core Samples." May 24, 2018. Accessed: Dec. 03, 2024. [Online]. Available: https://serc.carleton.edu/ANGLE/educational_materials/activities/205659.html
[19] "Education Activities - Women In Mining Education Foundation (WIMEF)." Accessed: Nov. 30, 2024. [Online]. Available: https://www.womeninmining.org/activities/
[20] United Nations Department of Economic and Social Affairs, "The importance of sustainable transport for the 2030 Agenda and the Paris Agreement," in *Sustainable Transport, Sustainable Development*, United Nations, 2021, pp. 2–13. doi: 10.18356/9789210010788c003.
[21] C. Wang and M. A. Burris, "Photovoice: Concept, Methodology, and Use for Participatory Needs Assessment," *Health Educ. Behav.*, vol. 24, no. 3, pp. 369–387, Jun. 1997, doi: 10.1177/109019819702400309.
[22] C. C. Wang, "Youth Participation in Photovoice as a Strategy for Community Change," *J. Community Pract.*, vol. 14, no. 1–2, pp. 147–161, Jan. 2006, doi: 10.1300/J125v14n01_09.
[23] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qual. Res. Psychol.*, vol. 3, no. 2, pp. 77–101, Jan. 2006, doi: 10.1191/1478088706qp063oa.
[24] J. J. Lee and J. Hammer, "Gamification in Education: What, How, Why Bother?," 2011.

[25] J. McGonigal, *Reality is broken: Why games make us better and how they can change the world*. in Reality is broken: Why games make us better and how they can change the world. New York, NY, US: Penguin Press, 2011, p. 388.
[26] R. W. Lent and S. D. Brown, “Social cognitive career theory at 25: Empirical status of the interest, choice, and performance models,” *J. Vocat. Behav.*, vol. 115, p. 103316, Dec. 2019, doi: 10.1016/j.jvb.2019.06.004.
[27] A. Bandura, *Self-Efficacy: The Exercise of Control*. Macmillan, 1997.
[28] A. Bandura, C. Barbaranelli, G. V. Caprara, and C. Pastorelli, “Multifaceted Impact of Self-Efficacy Beliefs on Academic Functioning,” *Child Dev.*, vol. 67, no. 3, pp. 1206–1222, 1996, doi: 10.1111/j.1467-8624.1996.tb01791.x.
[29] R. W. Lent and S. D. Brown, “On Conceptualizing and Assessing Social Cognitive Constructs in Career Research: A Measurement Guide,” *J. Career Assess.*, vol. 14, no. 1, pp. 12–35, Feb. 2006, doi: 10.1177/1069072705281364.
[30] S. D. Brown and R. W. Lent, “Social cognitive career theory,” in *Career psychology: Models, concepts, and counseling for meaningful employment*, Washington, DC, US: American Psychological Association, 2023, pp. 37–57. doi: 10.1037/0000339-003.