The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #42903

Evaluation of High School Semiconductor and Microelectronics Summer Program (Evaluation)

Shauna Adams, Purdue University

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 interest includes understanding the resources and supports provided to volunteers in precollege community-based engineering programs especialy programs for underrepresented groups in engineering, with a specific focus on Black/African American youth. Shauna is engaged in Purdue's Engineering Education Graduate Student Association and Black Graduate Student Association.

Mr. Cristian Eduardo Vargas-Ordonez P.E., Purdue University

Cristan Vargas-Ordonez is a Colombian Ph.D. Candidate and Research Assistant in Engineering Education at Purdue University. He has a Master's in Education from the University of Los Andes, a Master's in Science, Technology, and Society from the National University of Quilmes, and a Bachelor's Degree in Chemical Engineering from the University of America.

Dr. Morgan M Hynes, Purdue University

Dr. Morgan Hynes is an Assistant 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

Dr. Kerrie A Douglas, Purdue University

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.

Prof. Peter Bermel, Purdue University

DR. PETER BERMEL is an assistant professor of Electrical and Computer Engineering at Purdue University. His research focuses on improving the performance of photovoltaic, thermophotovoltaic, and nonlinear systems using the principles of nanophotonics. Key

Dr. David R. Ely, Ivy Tech Community College, Indianapolis

Dr. David R. Ely is the Engineering Program Chair at Ivy Tech Community College Lafayette since 2013. He enjoys teaching engineering students at Ivy Tech and advising them on the different engineering career paths that best match their interests and skill

Hayley Joy Grisez

©American Society for Engineering Education, 2024

Evaluation of High School Semiconductor and Microelectronics Summer Program (Evaluation)

Abstract

This paper presents an overall evaluation of the READI High School Semiconductor Summer Program, which aims to cultivate semiconductor awareness and interest among high school students. In response to the imperative for a skilled workforce in this industry, where semiconductor research, design, and fabrication occur, a large mid-western university and a local community college co-developed and implemented the first version of a 2-week summer program for local high school rising juniors and seniors. This initiative strives to increase students' knowledge of, awareness of, and interest in semiconductors by introducing them to the associated technology, manufacturing, applications, and careers within this ecosystem.

In particular, the program engaged fifty-three high school students from six regional counties in hands-on activities in electronics and manufacturing, visits to local companies using semiconductors in their production lines, tours of local higher education fabrication and experimental lab facilities, and designing and prototyping various microelectronic systems. The program and participant experience were evaluated based on understanding students' change in their sense of belonging and self-efficacy, career aspiration, and knowledge and skills associated with the semiconductor ecosystem. Data collection involved pre-post survey results, students' daily evaluations of the program activities and reflections, and focus group responses.

The analysis, employing inductive coding of responses and related pairs analysis on pre- and post-survey sections, revealed positive outcomes. These findings indicate that participants' knowledge of semiconductors and sense of belonging in the semiconductor ecosystem improved, and there was an increase in participant awareness of semiconductor career paths. While acknowledging the program's success in meeting its objectives, participants offered valuable insights for refining the program's curricular design in future iterations. These results increase awareness of an emerging field in the community, potentially serving as a model for precollege engineering summer programs associated with workforce development initiatives across different industries in the country.

Introduction/Background

In the dynamic landscape of today's semiconductor industry, companies are grappling with a multitude of challenges that transcend traditional operational hurdles. The persistent global semiconductor shortage, compounded by increased design complexity, talent shortages, pandemic-related disruptions, and increased demand, has spurred a transformative shift in the industry [1], [2]. The repercussions of these challenges are now reaching critical proportions, as evidenced by extended product lead times, automotive production delays, and a growing trend among major technology companies and automotive equipment manufacturers to internalize chip design [1], [2].

The semiconductor industry, encompassing diverse segments such as memory, logic, analog, discrete, optical components, and sensors, operates within a complex global supply chain from material procurement to backend manufacturing [3]. The intricacies of this supply chain underscore the industry's susceptibility to disruptions, making it imperative for companies to revisit their strategies in critical areas. According to Burkacky et al. [2], six critical dimensions are vital to the semiconductor industry's long-term success: technology leadership, long-term research and development (R&D), resilience, talent acquisition, ecosystem capabilities, and increased production capacity.

This evaluation paper focuses on talent development as a means to promote careers related to the semiconductor industry, aiming to facilitate a smoother talent acquisition process within this sector. Currently, the semiconductor industry grapples with a growing demand for skilled talent, attributed to the complexity of chip design and the substantial labor challenges it entails. Recognizing the need for a comprehensive approach, semiconductor companies seek to enhance workplace attractiveness to compete for top talent. Amidst this challenge, an economic acceleration and development initiative in a Midwestern state has developed a semiconductor high school summer program as a pioneer educational initiative projected to inspire future workforce in the semiconductor industry. Developed by a Community College and a large Midwestern Research University, this summer program aims to cultivate technical, operational, and engineering careers for the region's semiconductor industry.

In response to the growing demands of the semiconductor industry, this partnership launched a two-week summer program initiative to deepen the understanding and interest of local high school juniors and seniors in semiconductors, encompassing technology, manufacturing, industry applications, and career pathways. Engaging fifty-three students from six regional counties, the program featured hands-on electronics and manufacturing activities, company visits, and tours of university labs. This paper evaluates how the program achieved the goals of increasing students' sense of belonging and self-efficacy, career aspiration, and knowledge and skills associated with the semiconductor ecosystem. By unveiling key insights, this program evaluation provides recommendations for program stakeholders and developers, contributing valuable perspectives to the discourse on semiconductor workforce development programs.

Program Description

The region's economic development agency funded the summer program with engineering workforce development (EWD) goals to prepare a workforce for the semiconductor manufacturers the region is recruiting. The primary objectives of the summer program are to expose students to the semiconductor industry (knowledge, skills, and opportunities) and foster interest and engagement in the industry. The program is a collaboration between two higher education institutions where various pathways to careers in the semiconductor industry can be explored. Given the above goals of the summer program, a 10-day experience was designed for rising junior and senior high school students. The curriculum development team developed a schedule that included short lectures/speakers, tours of both campuses' facilities, tours of local manufacturing companies, and various hands-on/minds-on activities ranging from intro to electronics to designing and programming microcontroller creations. These activities are detailed below.

Short lectures/speakers

Several short lectures were included to introduce the various players in the program. These speakers covered a range of topics that included careers in the semiconductor industry, giving an elevator pitch, education pathways, applications for semiconductors in everyday life, and how semiconductors are manufactured.

Campus tours

Students toured engineering/technology buildings and spaces on both campuses. The primary intention of these tours was to allow the students to explore college campuses and better understand what a college pathway might look like for them. The students also spent an entire day touring various labs and manufacturing facilities within a large research center, which included visiting one of the largest educational clean rooms in the U.S. The tours introduced students to the state-of-the-art industry manufacturing processes for nano-scale semiconductor manufacturing. Students also toured labs highlighting how semiconductor products are applied in real-world contexts (e.g., solar energy production, agricultural sensing, and biomedical applications).

Industry Tours

Local industry tours were coordinated to show students how various companies use or manufacture semiconductor products. For example, students went on tours of a large automotive plant, a large engine plant, and a semiconductors manufacturing plant, where participants visited the facilities where electronic and power electronic components for hybrid vehicles are designed, manufactured, assembled, and tested. Participants got to see first-hand semiconductor integrated design, assembly, and testing. They rotated between different technical areas at the facility and talked with engineers, technicians, project managers, designers, and team leaders about their roles and experience with the company.

Advanced Manufacturing and Robotics Workshops

A robotics workshop was developed incorporating hands-on experiences with VEX Workcells and FANUC robots and explaining the role robots have in advanced manufacturing environments. There were four main objectives for the course.

- Develop foundational knowledge of industrial robotics: Students gained a comprehensive understanding of key concepts, preparing them for further exploration in the field.
- Bridge the gap between theory and practice: The VEX Workcells challenges provided a practical platform to apply theoretical knowledge to real-world scenarios.

- Introduce advanced FANUC programming: Students learned to code for more complex industrial robots, equipping them with valuable skills relevant to the semiconductor industry.
- Spark interest and encourage future exploration: The engaging activities aimed to ignite a passion for industrial robotics, potentially inspiring students to pursue careers in this rapidly evolving field.

Electronics Workshop

An electronics workshop delved into the electronics world was developed, empowering students to build and showcase their very own 9V battery testers. Through hands-on exploration and expert guidance, participants gained a deeper understanding of fundamental electrical principles and their connection to the ever-evolving semiconductor industry. Program participants explored basic concepts like voltage, current, and resistance, laying the groundwork for understanding circuit behavior. Under the staff's watchful eyes and hands-on guidance, they learned proper soldering techniques, connecting electronic components with precision and confidence. Students explored how resistors and LEDs to circuit boards and zener diodes interact within circuits. This exposure sparked curiosity and fostered a deeper understanding of the building blocks of electronic devices.

Hands-on Electronics

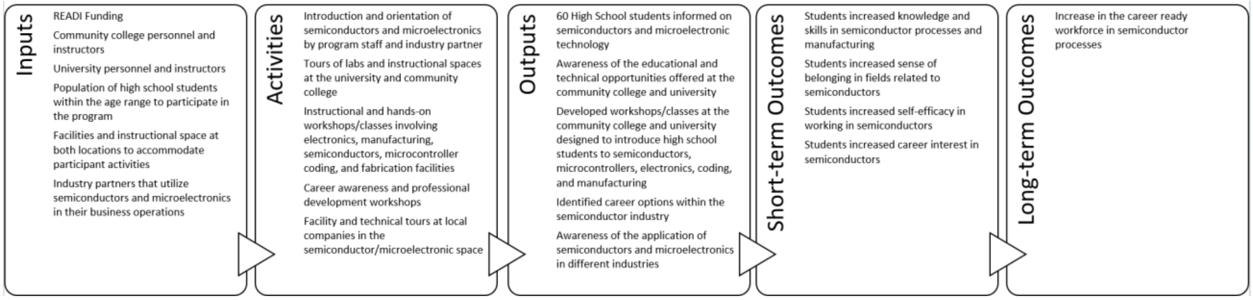
Two sets of hands-on electronic activities were developed. One set of activities introduced students to simple circuits by exploring various electronics kits and toys. These activities are aimed at teaching students with limited knowledge or experience basic electronics concepts or acting as a refresher for those with more knowledge and experience. The students then transitioned to a 3-day unit called Paper Electronics. Paper Electronics tasked the students with using low-cost materials and an Arduino microcontroller to solve a problem their team was interested in. Students learned about circuits and microcontrollers' essential components, how to program the Arduino microcontrollers, and then designed and created microcontroller-based solutions to personally meaningful problems.

Methods

A formative participatory evaluation looks at year 1 of a 3-year funded program. Program administrators and researchers use evaluation results to improve program function, inform pedagogical supports, and assess alignment with program objectives. The internal program evaluation model in **Figure *1*** is structured as described in the National Science Foundation's (NSF) handbook on program evaluation [4].

Figure 1

Program Evaluation Logic Model



Participants and Recruitment

Participants for the summer program consisted of high school-aged teens entering their junior and senior years of high school. The program's goal was to recruit sixty teens. Participants were informed of this program through local schools, community groups, and word of mouth. Flyers were sent and hand-delivered to schools in every county, and emails explaining the program were sent to school career counselors and county stakeholders for distribution. The community college provided school contacts through its partnerships with the local high schools. Participant exposure to semiconductors and electronics ranged from no exposure to advanced knowledge through school coursework or extracurricular activities. As a funding requirement, program participants were required to come from the six counties representing the region of the funding source. This was screened using questions in the initial application. One program participant did not complete the initial application; however, their information was verified through other source documents. The demographic information of all participants was retained and reported; however, for research purposes, only survey responses from the participants who consented and completed the post-survey will be reported. This includes forty participants. Reflection responses will only be reported from those who consented and responded totaling 167 responses from forty participants. In total, fifty-five teens were accepted into the program. This accounts for all eligible applicants who applied to the program. Two participants dropped out of the program before or immediately after the first day of orientation.

All applicants who completed the application and met the eligibility requirements were accepted into the program. This total accounts for fifty-five teens. Participants were asked for consent or assent for their data to be analyzed for research purposes. Only those that affirmed were included in the results of the paper. For data reporting purposes, the applicant's data not collected through the formal collection process was classified as undisclosed for all the reported parameters. There was an even split of applicants across grade levels; twenty-seven selected “Junior in the Fall of 2023,” and twenty-seven selected “Senior in the Fall of 2023”. For selection of sex, six applicants selected “Female,” and forty-eight applicants selected “Male” for their sex. All six counties representing the funding organization were represented. **Figure *2*** compares applicants to proportional numbers based on county census data [5]. Race and ethnicity data for applicants compared to census data is shown in **Figure *3***. The applicant pool for the program aligned closely with the area's demographics.

Figure 2

Applicants Represented by County

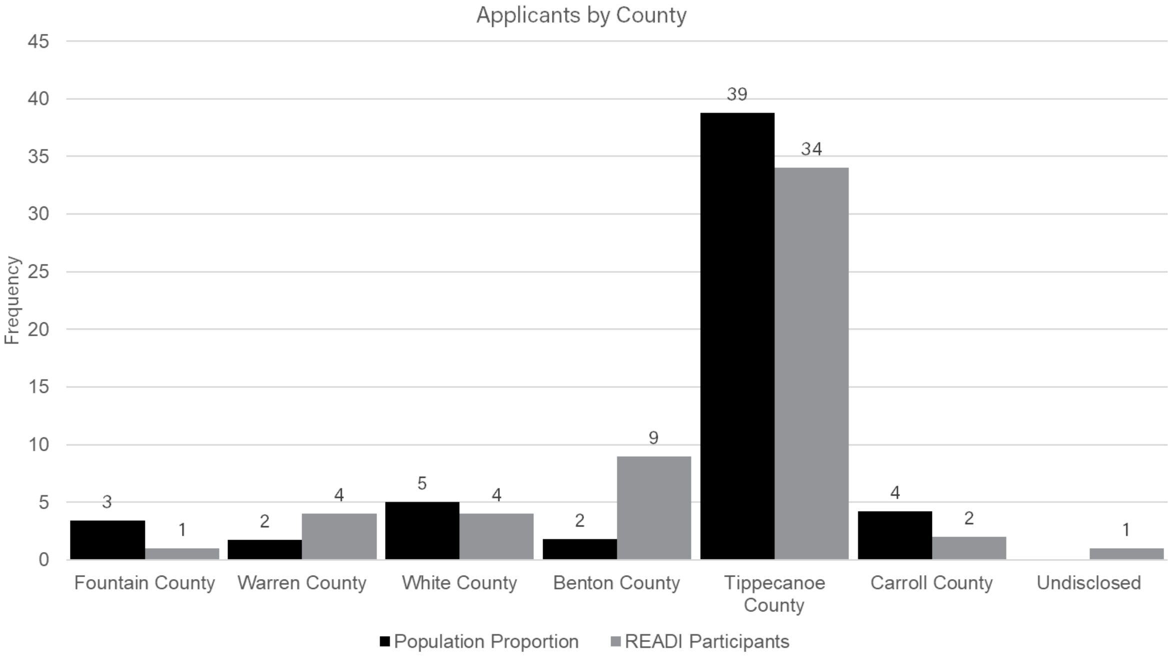
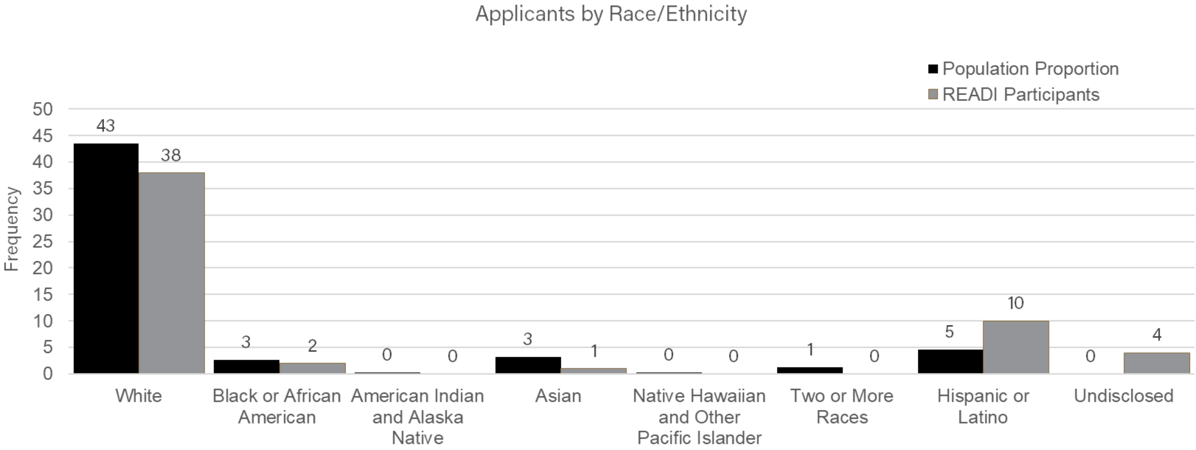


Figure 3

Applicants by Race/Ethnicity



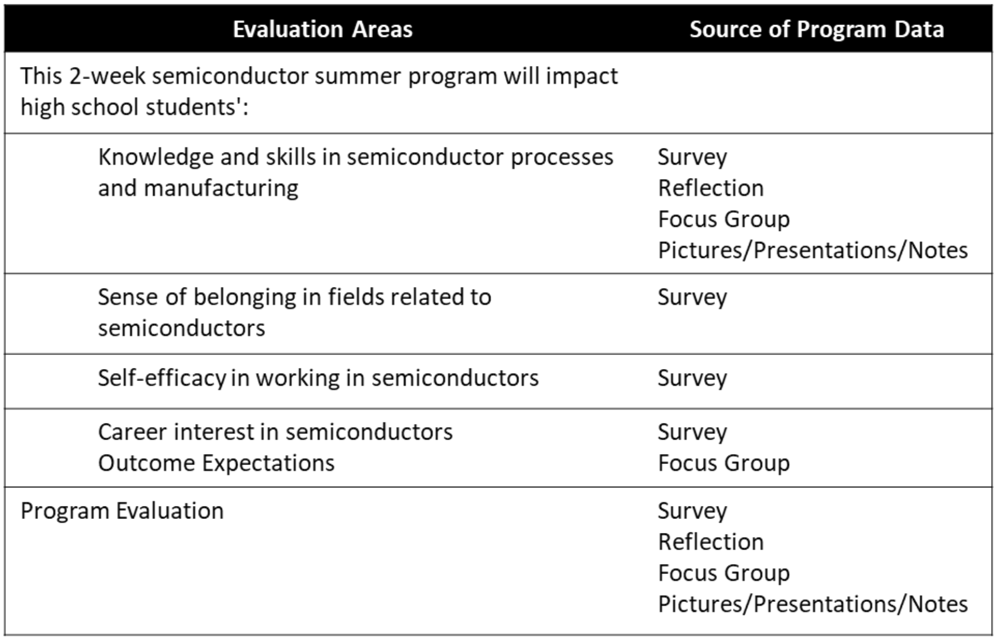
Data collection

A combination of surveys, daily reflections, focus group responses, and observations were used to gather information from participants that informed the program team on the likelihood that program objectives were met.

Figure *4* shows the alignment of the evaluation question, the source of data, and what was measured.

Figure 4

Evaluation Data Source Chart



Evaluation Areas	Source of Program Data
This 2-week semiconductor summer program will impact high school students':	
Knowledge and skills in semiconductor processes and manufacturing	Survey Reflection Focus Group Pictures/Presentations/Notes
Sense of belonging in fields related to semiconductors	Survey
Self-efficacy in working in semiconductors	Survey
Career interest in semiconductors Outcome Expectations	Survey Focus Group
Program Evaluation	Survey Reflection Focus Group Pictures/Presentations/Notes

<u>Pre- and Post-Surveys</u>

Three different assessment tools were used to create sections of the pre- and post-survey. The assessments were used to examine participant knowledge and skills in semiconductor processes and manufacturing, their career interest in semiconductors, their perceived sense of belonging if they entered the fields related to semiconductors, and their self-efficacy in working in related jobs. A series of Likert Scale questions and two dichotomous yes/no questions in the post-survey gathered information on program feedback and questions about post-high school plans. The pre- and post-surveys asked participants about their career interests or anticipated majors.

Parts of the Knowledge, Awareness, and Motivations (KAM) survey tool were modified to evaluate awareness, exposure, career interest, and motivations. The KAM survey is a modified version of the *Motivation and Exposure in Microelectronics Instrument* [6], an instrument derived from the *Nanotechnology Awareness Instrument* [7]. The instrument was initially developed to assess changes in awareness, exposure, motivation, and knowledge of nanotechnology [7]. To measure students' self-efficacy and career outcome expectations, we administered a modified *Social Cognitive Career Theory Survey* (SCCT) [8]. The *Microelectronics SCCT Survey* focuses on the fundamental tenets of SCCT that look at the impact self-efficacy, choice goals, interest, outcome expectation, barriers, and supports have on career outcomes [8]. Lastly, part of the *Adapted Perceived Cohesion* scale was modified to evaluate the perceived sense of belonging [9].

The pre- and post-survey consisted of two open-ended questions to capture the awareness of semiconductor technology applications in participants' current and future life were adapted from recent versions of the KAM instrument [7]. The post-survey consisted of additional free-response questions not found in the pre-survey to capture program feedback. Two questions were posed in both the pre- and post-survey, while an additional five questions were exclusively included in the post-survey.

Daily Reflections

The daily reflection form consisted of two open-ended questions to bridge connections between program activities and their applicability to the semiconductor industry. The form also collected participant feedback on the day's activities consisting of multiple-choice questions and an optional open-ended question to provide written feedback. Participants were asked to complete daily reflections after each day of program activities.

Focus Groups

On the last day of the program, participants were divided into focus groups ranging in size between five and seven participants. All participants present on the last day participated in the focus group. Those who did not provide consent or assent were all assigned to the same group so that their responses could be gathered for program purposes but not used in research reporting.

The focus group protocol focused on their program experience and their introduction to career options. Thirteen open-ended questions were included in the focus group protocol.

Data analysis

This paper presents the outcomes from analyzing pre-post surveys and daily reflections. The pre-post surveys and reflections analysis involved a comprehensive approach utilizing descriptive statistics and repeated measures/related sample testing. Descriptive statistics, employing frequency tables, were used to capture feedback from multiple-choice activity questions and the exclusive multiple-choice and dichotomous questions in the post-survey. For the repeated measures/related samples testing, assessing pre- and post-survey responses corresponding to different assessment scales, the research team contemplated the use of a matched pairs t-test or a nonparametric Wilcoxon Signed Ranked Test. These tests are designed for within-group analysis, focusing on data collected from the same group before and after applying a specific condition in this study: participation in the summer program. The matched pairs t-test assumes independence across participants and a normal distribution in the differences of scores between pre- and post-survey responses. The nonparametric Wilcoxon Signed Ranked Test was employed when these assumptions were unmet.

In analyzing the qualitative data, we conducted a Qualitative Content Analysis focused on the data obtained from the open-ended survey questions. Employing an inductive approach, we adopted a data-driven strategy which, according to Schreier, allows categories to emerge from the collected material naturally[10]. The coding process followed William and Moser's suggestion on qualitative data analysis [11], which involved an initial generation of open codes, capturing the diversity of responses of the participants. Subsequently, we established broader categories, identifying recurring themes that surfaced with greater frequency. From these categories, we selected those deemed most relevant to address the overarching research question. This process was done simultaneously by the two first authors to ensure that codes were trustworthy, meaningful, and comprehensive.

Results

The Wilcoxon Signed Ranked Test was used to analyze the data for pre- and post-survey responses that looked at awareness and exposure, motivation, sense of belonging, outcome expectations, and self-efficacy. For this analysis, the null hypothesis was that the median difference in pre- and post-ranking is 0. Three areas were significant with p-values less than .05, thus rejecting the null hypothesis. Participant responses to the awareness and exposure ($p <$ .001), sense of belonging (p = .01), and self-efficacy (p = .04) sections showed significant differences in responses after participating in the summer program. The majority of those differences were positive in each case. The pre- and post-survey differences were insignificant for the other areas of motivation (p = .29) and outcome expectations (p = .81).

The survey results were out of 40 participant responses (n = 40). For the multiple-choice career question described in Table 1, 90% of respondents were either interested in learning about semiconductor-related careers, pursuing training, or have decided to go into semiconductor-related careers. For the Likert Scale program feedback questions listed in **Figure *5***, 80% or more of respondents selected "Agree" or "Strongly Agree," and 2.5% or less of respondents chose "Strongly Disagree" or "Disagree" for each question. When asked about the stipend, 95% of respondents indicated it was a motivating factor for participating in the program. 97.5% of respondents indicated they would recommend the program to friends or other peers, as shown in **Table *2***.

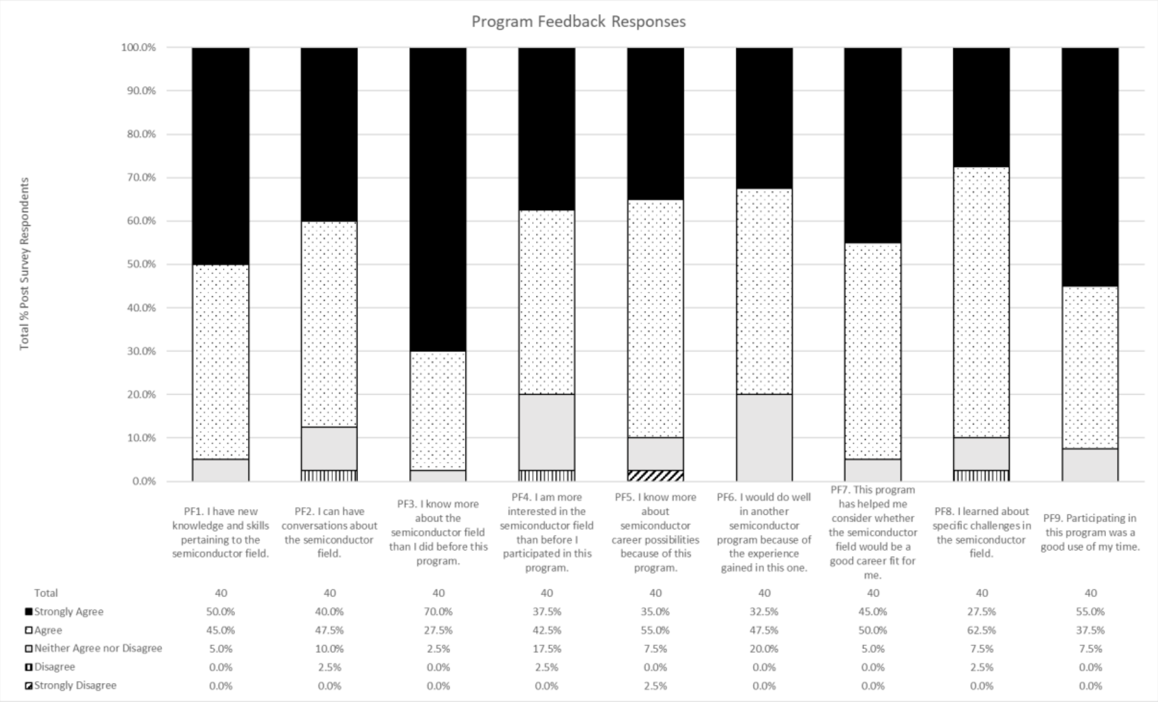
Table 1

Career Interest Multiple Choice Question Responses

	I am pursuing training and/or educational opportunities for a career related to semiconductors.	I have decided to go into a field related to semiconductors.	Open to learning more	Not interested
How interested in semiconductor-related careers are you?	3	7	26	4
	7.5%	17.5%	65.0%	10.0%

Figure 5

Program Feedback Multiple Choice Feedback Responses



	PF1. I have new knowledge and skills pertaining to the semiconductor field.	PF2. I can have conversations about the semiconductor field.	PF3. I know more about the semiconductor field than I did before this program.	PF4. I am more interested in the semiconductor field than before I participated in this program.	PF5. I know more about semiconductor career possibilities because of this program.	PF6. I would do well in another semiconductor program because of the experience gained in this one.	PF7. This program has helped me consider whether the semiconductor field would be a good career fit for me.	PF8. I learned about specific challenges in the semiconductor field.	PF9. Participating in this program was a good use of my time.
Total	40	40	40	40	40	40	40	40	40
■ Strongly Agree	50.0%	40.0%	70.0%	37.5%	35.0%	32.5%	45.0%	27.5%	55.0%
□ Agree	45.0%	47.5%	27.5%	42.5%	55.0%	47.5%	50.0%	62.5%	37.5%
▣ Neither Agree nor Disagree	5.0%	10.0%	2.5%	17.5%	7.5%	20.0%	5.0%	7.5%	7.5%
◧ Disagree	0.0%	2.5%	0.0%	2.5%	0.0%	0.0%	0.0%	2.5%	0.0%
◩ Strongly Disagree	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%

Table 2

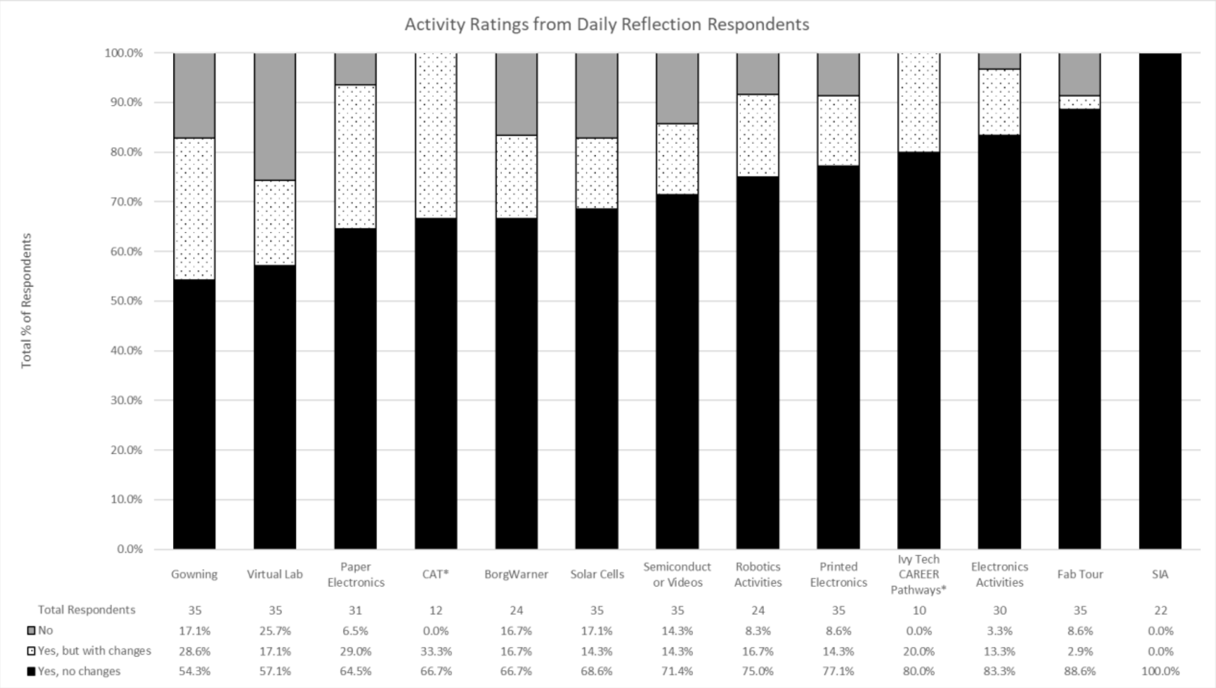
Dichotomous Program Feedback Responses

	No	Yes
Was the stipend a motivating factor in you participating in this summer program?	2	38
	5%	95%
Would you recommend this program to your friends and other peers in your school and community?	1	39
	2.5%	97.5%

On the other hand, the total number of participants who completed the daily reflections varied from day to day. Completing reflections was highly encouraged by program leadership but was optional for the final stipend payment. This may have limited participation. As shown in **Figure *6***, 80% of respondents would recommend again, with no or some changes to all of the activities from the program. Participants had a space where they could provide written feedback if changes were recommended.

Figure 6

Program Activity Feedback Results



	Gowning	Virtual Lab	Paper Electronics	CAT*	BorgWarner	Solar Cells	Semiconduct or Videos	Robotics Activities	Printed Electronics	Ivy Tech CAREER Pathways*	Electronics Activities	Fab Tour	SIA
Total Respondents	35	35	31	12	24	35	35	24	35	10	30	35	22
▨ No	17.1%	25.7%	6.5%	0.0%	16.7%	17.1%	14.3%	8.3%	8.6%	0.0%	3.3%	8.6%	0.0%
☐ Yes, but with changes	28.6%	17.1%	29.0%	33.3%	16.7%	14.3%	14.3%	16.7%	14.3%	20.0%	13.3%	2.9%	0.0%
■ Yes, no changes	54.3%	57.1%	64.5%	66.7%	66.7%	68.6%	71.4%	75.0%	77.1%	80.0%	83.3%	88.6%	100.0%

*Part of the participants attended the Caterpillar Plant Tour (~30 participants), and the other part participated in the community college CAREER Pathways Discussion (~22 participants)

Qualitative results show a positive perception of the program. More in detail, when asking the participants in the post-survey about the **types of semiconductor-related jobs they are interested in,** their answers varied from unspecific, or "anything," to specific in relation to the topics, careers, areas, or places they are interested in working in (*n* = 40). Fifty-eight percent of the participants manifest a specific interest in a semiconductor industry career, mentioning either an area (development, operation, design, or sales), a topic (computer hardware; computer programming; cars, planes, trains, trucks, or trains; soldering; or robotics), a technical or professional major in engineering (mechatronic, electrical, or mechanical), or a place (Removed). On the other hand, 31% of the participants, with unspecific interests, settled on broader areas like design, electricity, electronics, and manufacturing. Eleven percent of the participants specified their interest in a particular career (computer engineering or electrical engineering) and topic (circuit design, robotics, computer electronics manufacturing, engineering design, or ICs and ECUs).

We also asked the participants what would be **meaningful for them about pursuing a career in semiconductors, microelectronics, or advanced manufacturing**. The participants generally split into two groups (*n* = 42). On the one hand, 45% of the participants considered pursuing a career in the semiconductors industry to impact the broader society through solving technological challenges or increasing the offer of semiconductors and microchips to help society's daily life needs. On the other hand, 55% of the participants considered the possibility of getting individual gains, such as learning about semiconductors or a future job in a perceived supportive environment where they can explore their particular interests.

Regarding **what the participants liked most about the program** (*n* = 40), the appreciation for hands-on activities was the most prominent theme, identified by 18% of the participants, highlighting the significance of interactive learning experiences. Following, meeting like-minded people, networking, and attending the tours to different semiconductor companies, each of them with 13%, emerged as other essential aspects, emphasizing the value of social interactions within the program. On the other hand, other respondents enjoyed paper electronics (8%) and semiconductor applications (8%) as topics that showcased an interest in the practical and technological aspects of the program. Other notable categories included activities at the REMOVED Nanotechnology Center (5%), circuits and coding notions (5%), the overall program experience (5%), and the teamwork-based nature of the program (5%). Furthermore, participants found value in gaining insights into career pathways (3%), the program's environment (3%), stipend (3%), and the combination of challenging yet meaningful experiences (3%).

Similarly, when asked about the **suggestions about the program** (*n* = 48), most participants revealed that they desire more hands-on activities and projects (22%), underscoring the importance of interactive and practical learning experiences. Additionally, they emphasized that while semiconductor tours were interesting, there was a perceived need for a more engaging and participatory approach, expressing a desire for less passive observation and more hands-on involvement in semiconductor-related activities (20%). Similarly, the participants highlighted the importance of receiving more in-depth information on semiconductors at an undergraduate level (13%), indicating a preference for a comprehensive and educational experience. According to some participants, learning more in-depth content would imply a more rigorous application process (9%) to ensure a higher level of commitment and engagement from participants. A different perspective about how this intersects with the goals of the program is provided in the next section.

Other notable feedback points included the request for improved lunch selections (7%) and the avoidance of online activities (7%), emphasizing a preference for in-person engagement over virtual alternatives. Participants also desired less semiconductor lecture time (7%), addressing the need for a balanced program structure. Some specific concerns were also noted, such as issues with the online folder (4%) and the request for better communication (2%). Additional suggestions included reducing standing time (2%), making the program more interesting (2%), and shortening the scavenger hunt activity at the beginning of the program (2%). Finally, participants expressed interest in some form of follow-up or continuation of the program (2%) and a desire to discuss actual jobs related to the semiconductor industry (2%).

An analysis of participants' **sources of information about the program** *(n* = 40) revealed that most participants (44%) learned about the program through schoolteachers across different areas or counselor announcements, emphasizing the pivotal role of educational institutions in disseminating information about extracurricular opportunities. Additional communicative media include emails from teachers (38%), reaching parents through school channels, underscoring the effectiveness of direct communication within the school community. A smaller but still sizable portion of participants discovered the program through family or friends (10%). School posters were also cited as a source of information (5%). Lastly, few participants learned about the program through church newsletters (3%), indicating the diverse channels through which information reached potential participants.

Upon comparing pre- and post-responses (*n* = 40), some participants exhibited consistency (68%) and other growth (29%) in their **understanding of how semiconductors directly impact their lives**. Similar responses emerged regarding participants describing how semiconductors are merged into their daily routines and the various applications that rely on these components. Notably, the ubiquitous presence of semiconductors in cellphones and computers resonated consistently among participants. On the other hand, other participants demonstrated an enhanced grasp of semiconductor functions, transitioning from high-level systems such as radars and security applications to recognizing the direct influence of semiconductors in personal devices like computers and cell phones. Some participants expanded their comprehension from personal applications to higher-level systems, while others moved in the opposite direction, acknowledging the integral role semiconductors play in both realms. Furthermore, there was a noticeable advancement in participants' understanding of the relationship between semiconductors and computers, highlighting the expanding scope and significance of these electronic components in shaping the contemporary technological landscape. In general, the responses showed the participants' diverse levels of understanding of semiconductors, meaning that some participants had more experience prior to this program than others about this topic. Finally, when asked about **how working in the semiconductor field may directly impact the participants life in the future**, the responses suggest the participants broadened their perspective towards the possibles impacts either on society through technological development or novel work of opportunities.

Implications/Discussion

The findings indicate an overall satisfaction among participants with the REMOVED summer program. Nonetheless, opportunities for enhancing future versions of the program were identified. Specifically, areas such as recruitment and pedagogical strategies present avenues for improvement. Addressing these aspects is crucial, as they can influence the program's overarching goals, including self-efficacy, sense of belonging, awareness, motivation, and outcomes expectations. Recognizing and refining these elements will contribute to the continued success and effectiveness of the program.

Results showed a significant change in self-efficacy, sense of belonging, and awareness of semiconductors and career opportunities within the semiconductor industry. Self-efficacy is one's belief about one's capability to do or understand something, and a sense of belonging is a person’s perceived connectedness and support within a particular area [8], [9]. These two things result from awareness in a subject area and engagement with others in the subject area. Since many of the program participants had little to no exposure to the semiconductor industry, it is understandable that there were improvements in these areas after two weeks of exposure to a specific topic. However, motivation occurs after repeated exposure and awareness of a certain subject [7]. There was no significant change in motivation for participants to pursue semiconductor careers. This may be attributed to the length of the program and the fact that this was the first touchpoint with many participants. To improve this area, the program may consider additional ways to stay connected to participants to increase their exposure and awareness of opportunities to be informed and advance in semiconductor knowledge.

School outreach was the primary mechanism for recruitment for the program for the first year. Most participants heard of the program through their schools, and several identified teachers who encouraged them individually or their class to participate. This personal invitation and motivation from teachers/staff align with other programs where schools and faculty/staff were recruitment sources [12]. Another area that impacted recruitment was offering a program stipend. Almost every participant responded that the stipend was a motivating factor for applying to the program. Competing with youth employment opportunities stipends provide teens options for participating in alternative summer opportunities [13]. Recruiting those who identify as girls for the program was an area of improvement. Girls' participation in the program was below census representation of about 50% but even more comparatively below industry standards [5]. According to the Global Semiconductor Alliance, the median representation of women in the semiconductor industry is currently between 20-25% and 10-15% in technical areas, with hiring in both areas increasing [14]. Targeted efforts to improve participation in the future include modifications to program marketing materials, diversity in representation of program champions in classrooms and the community, and visiting tech-ed and non-tech-ed classrooms to reach students not already on the tech-ed pathway.

A few participants expressed that delving into in-depth content should be accompanied by a more rigorous application process to ensure a heightened level of commitment and engagement. While such a perspective aligns well with programs emphasizing academic excellence in fields like semiconductors, creating barriers to entry diverges from the goals of our developed program. Our primary objective is to cultivate positive perceptions and encourage individuals to explore career pathways in the semiconductor industry and engineering, moving away from the idea that engineering is only for smart people, as the National Academy of Engineering has previously mentioned [15]. In this context, inclusivity is paramount, and our program is designed to welcome participants independently of their knowledge of the subject matter. To address potential gatekeeping tendencies, future versions of the summer program will incorporate activities that challenge preconceived notions about who can become an engineer to foster a more inclusive and diverse learning environment as aligned with the CHIPS and Science Act to continuously provide “STEM opportunities to more of America to participate in good-paying skilled jobs,”[16], through this type of educational programs.

Regarding the pedagogical approach employed in the program, the participants generally reported positive self-perceptions regarding their grasp of fundamental semiconductor concepts through various semiconductors-related topics and activities. According to their feedback, hands-on activities were crucial in facilitating this understanding. This favorable view aligns with findings from other studies [17], [18], [19], [20]. Conversely, when participants encountered fewer hands-on activities, they desired more interactive opportunities, emphasizing a need to create and apply their newfound knowledge. Furthermore, some participants noted instances where certain activities introduced new concepts that needed more reinforcement through hands-on engagement. This observation corresponds with Bloom's taxonomy, emphasizing that more meaningful learning occurs when higher-order verbs are targeted [21]. This implies a shift away from traditional lecture-based explanations towards creating learning experiences where participants actively interact with tools, materials, and other relevant elements related to the topic, fostering the generation of solutions. Focusing more on problems and project-based approaches may enhance the meaningful acquisition of semiconductor-related knowledge.

Conclusions and implications

Overall, participants expressed a favorable experience with the program, citing various reasons for their positive feedback. Notably, they highlighted the program's effectiveness in aiding them in making informed career decisions within the semiconductor industry. Participants found value in the program's ability to enhance their resumes, expand their knowledge in semiconductors, foster social connections, and expose them to diverse career possibilities.

One of the program's key strengths is its emphasis on practical applications of the content delivered, encouraging active engagement with the subject matter. This approach contributed significantly to the positive outcomes reported by participants.

However, there are challenges that merit attention for future iterations of the program. Improving and broadening the recruitment process is crucial to maintaining the positive perception of the program and enhancing the involvement of women and underrepresented communities. A more focused and intentional recruitment strategy should be implemented, complemented by efforts to sustain the stipend as an effective incentive. Addressing these challenges will enhance the program's impact and inclusivity in subsequent offerings.

References

[1] A. Chakraborty, "Global semiconductor shortage triggering obstructions and production delays," *Glob. J. Bus. Integral Secur.*, 2016.

[2] O. Burkacky, M. de Jong, and J. Dragon, "Semiconductors practice: strategies to lead in the semiconductor world," McKinsey & Company, Apr. 2022.

[3] F. Olivieri, "A secondary sources analysis of the business models and supply chain strategies of semiconductor manufacturers," Politecnico di Milano, 2021.

[4] J. A. Frechtling, *The 2010 user-friendly handbook of project evaluation*. National Science Foundation, Directorate for Education and Human Resources, Division of Research and Learning in Formal and Informal Settings, 2010.

[5] U.S. Census Bureau, "Indiana quick facts." U.S. Census Bureau, 2023. [Online]. Available: https://www.census.gov/quickfacts/IN

[6] A. Gentry, E. Holloway, P. Bermel, and K. Douglas, "Validity evidence for exposure and motivation scales in a microelectronics workforce development program," presented at the 2022 ASEE Annual Conference & Exposition, Aug. 2022. Accessed: Jan. 19, 2024. [Online]. Available: https://strategy.asee.org/validity-evidence-for-exposure-and-motivation-scales-in-a-microelectronics-workforce-development-program

[7] M. A. Dyehouse, H. A. Diefes-Dux, D. E. Bennett, and P. K. Imbrie, "Development of an instrument to measure undergraduates' nanotechnology awareness, exposure, motivation, and knowledge," *J. Sci. Educ. Technol.*, vol. 17, no. 5, pp. 500–510, Oct. 2008, doi: 10.1007/s10956-008-9117-3.

[8] 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.

[9] A. N. Gentry, K. Douglas, and J. P. Martin, "Undergraduates' perceived cohesion with their university during pandemic instruction.," *Annu. Meet. Program Am. Educ. Res. Assoc.*, Jan. 2022, doi: 10.3102/IP.22.1892849.

[10] M. Schreier, *Qualitative content analysis in practice*. SAGE Publications, 2012.

[11] M. Williams and T. Moser, "The art of coding and thematic exploration in qualitative research," *Int. Manag. Rev.*, vol. 15, no. 1, pp. 45–55, 2019.

[12] M. Yilmaz, J. Ren, S. Custer, and J. Coleman, "Hands-on summer camp to attract K–12 students to engineering fields," *IEEE Trans. Educ.*, vol. 53, no. 1, pp. 144–151, Feb. 2010, doi: 10.1109/TE.2009.2026366.

[13] L. Murray, C. Ogletree, and J. Lawrence, "Stipends as a tool to advance economic and educational equity in youth development programs," After School Matters, 2021.

[14] GSA, "GSA brief: women in the semiconductor industry 2022," Global Semiconductor Alliance (GSA), 2022. [Online]. Available: https://www.gsaglobal.org/wp-content/uploads/2022/11/GSA-ACN-2022-Women-in-Semiconductor-BRIEF-Final.pdf

[15] National Academy of Engineering, *Changing the conversation: messages for improving public understanding of engineering*. Washington, D.C.: National Academies Press, 2008, p. 12187. doi: 10.17226/12187.

[16] National Science Foundation, "Dear Colleague Letter: Equitable and Transformative Approaches to Educating the Semiconductor Workforce (ETA-ESW) (nsf23118) | NSF - National Science Foundation," Jun. 13, 2023. Accessed: Feb. 08, 2024. [Online]. Available: https://www.nsf.gov/pubs/2023/nsf23118/nsf23118.jsp

[17] N. T. Long, N. T. H. Yen, and N. Van Hanh, “The role of experiential learning and engineering design process in K-12 STEM education.,” *Int. J. Educ. Pract.*, vol. 8, no. 4, pp. 720–732, 2020.

[18] D. Pusca, R. J. Bowers, and D. O. Northwood, “Hands-on experiences in engineering classes: the need, the implementation and the results,” *World Trans Engng Technol Educ*, vol. 15, no. 1, pp. 12–18, 2017.

[19] D. M. Sianez, M. A. Fugère, and C. A. Lennon, “Technology and engineering education students’ perceptions of hands-on and hands-off activities,” *Res. Sci. Technol. Educ.*, vol. 28, no. 3, pp. 291–299, 2010.

[20] A. Suarez, D. García-Costa, J. Perez, E. López-Iñesta, F. Grimaldo, and J. Torres, “Hands-on learning: assessing the impact of a mobile robot platform in engineering learning environments,” *Sustainability*, vol. 15, no. 18, p. 13717, 2023.

[21] M. Forehand, “Bloom’s taxonomy: original and revised,” *Emerg. Perspect. Learn. Teach. Technol.*, vol. 8, pp. 41–44, 2005.