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Bridging the Gap: Exploring Semiconductors Exposure and Motivation among Multidisciplinary Engineering Students

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Bridging the Gap: Exploring Semiconductors Exposure and Motivation among Multidisciplinary Engineering Students

Abstract

Several educational initiatives are currently underway to address workforce challenges in the semiconductors industry. Assessing students' exposure to and motivation for semiconductors-related topics is an essential initial step toward recognizing areas where primary efforts should be concentrated. This study's main objective is to assess students' exposure and motivation concerning semiconductors in the context of a multidisciplinary introduction to electrical engineering course. Through quantitative analysis and the administration of an existing validated survey instrument, we aim to explore students' exposure to semiconductors-related topics and potential correlations between exposure, motivation, and demographic variables, including gender, class standing, and majors.

The instrument was administered to a cohort of 255 students enrolled in "Elements of Electrical Engineering," a multidisciplinary course covering the fundamentals of electrical engineering. Preliminary data indicates that only 9% of the students in this cohort have taken a class about semiconductors and only 3% have some interest in pursuing a career in the semiconductors field. The results of this analysis hold significant implications for engineering education and the semiconductor industry. The limited exposure to and interest in semiconductors among engineering students suggests the need for curriculum alignment with the demands of the semiconductor industry and interdisciplinary education. By doing so, we empower students from diverse disciplines to contribute to technological advancements, innovation, and problem-solving fostering a more inclusive, diverse, and well-rounded workforce within the semiconductor sector.

Background

The shortage of skilled workers in the semiconductor industry has become a pressing concern in the United States [1] with the Semiconductor Industry Association (SIA) estimating that the industry will need to fill approximately 115,000 jobs by 2030 [2,3]. To address this issue, the SIA organized the Workforce Development and Education Roundtable in July 2023 which brought together leaders from various sectors to discuss strategies for building a skilled semiconductor workforce. One of the key takeaways from the roundtable was the importance of partnerships between government, industry, and academia in creating effective workforce development programs that align with industry needs. One specific recommendation is to attract more STEM students to job opportunities in the semiconductor industry [4, 5]. Engineering graduates are often ill prepared for the workforce [6], especially in semiconductor industry [7]. Early exposure can have a significant impact on student interest [8,9, 10], motivation and career choices [11,12]. Furthermore, studies have emphasized the importance of early exposure to STEM education and hands-on learning experiences in fostering a diverse and talented workforce [13]. To address the skills shortage in the semiconductor industry, academic institutions and industry partners must work together to develop and implement effective workforce development programs. College of engineering mission statements often emphasize creating curricula that align with industry needs and providing students with practical, hands-on experience and mentorship opportunities [14,15,16].

In this paper, we assess students' exposure to and motivation for semiconductors-related topics in a multidisciplinary introductory electrical engineering course. The study is conducted in a multidisciplinary course, which includes students from various engineering majors, recognizing the importance of interdisciplinary education which can better reflect the real-world collaboration and problem-solving skills needed in the semiconductor industry. By understanding the current level of awareness and interest in semiconductors among engineering students, we aim to identify areas of improvement to encourage and prepare the next generation of semiconductor professionals.

Research Questions

The overarching aim of this study is to explore to what extent do students demonstrate their exposure and motivation for semiconductor-related topics within the context of a multidisciplinary electrical engineering course. To achieve this objective, the following research questions will be explored:

1.1 What levels of exposure and motivation for semiconductor-related topics do students express in a multidisciplinary electrical engineering course?
1.2 Are there differences in exposure and motivation levels in relation to semiconductor-related topics across genders, academic standing, and engineering majors?

Methodology

In this paper, we explored students' exposure and motivation for engaging in semiconductor-related activities in the context of an interdisciplinary elementary electrical engineering course. The study, which was conducted under an IRB-approved protocol using a pre-experimental research design, involved administering a survey at the end of the course. This survey was adapted from the nanotechnology awareness instrument originally developed by Dyehouse et al [17]. Specifically, we focused on the exposure and motivation scales of this instrument, designed to assess students' levels of exposure to and motivation for learning about nanotechnology. To align it with the context of this paper, we substituted the term "nanotechnology" with "semiconductors." The concept of exposure relates to activities that students have actively undertaken, such as reading about semiconductors while the concept of motivation aims to capture the types of future studies or work related to semiconductors that students plan to pursue. The rationale to utilize this existing instrument was to leverage in its established validity and reliability while tailoring specific sections to focus more directly on semiconductor-related concepts.

The instrument was applied to a cohort of 255 students in “Elements of Electrical Engineering,” a 3-credit multidisciplinary electrical engineering course at a doctoral university with high research activity in the southern part of US during the Summer of 2023. The course is required for all non-electrical engineering major students, as it covers a large portion of knowledge tested on the Fundamentals of Engineering (FE) Exam administered by the National Council of Examiners for Engineering and Surveying (NCEES). Participants identified themselves as 65.23% male, 32.42% female, and 2.34% non-binary. Figure 1 shows the distribution by gender. In terms of ethnicity/race, participants were 80.47% white, 10.16% Asian, 4.69% Black or African American, 0.39% American Indian, and 0.39% Native Hawaiian, and 3.91% prefer not to answer. Figure 2 shows the distribution by ethnic background. The largest part of the cohort were mechanical engineering majors (26.95%), followed by aerospace engineering (17.19%) and civil and coastal engineering (15.23%). This is in line with the number of undergraduates in the respective departments at the university surveyed. Electrical engineering students are not included because they are required to take "Circuits I," a 4-credit course with a dedicated weekly lab session. Figure 3 shows the distribution by major. Additionally, as figure 4 indicates, over 50% of the participants were juniors.

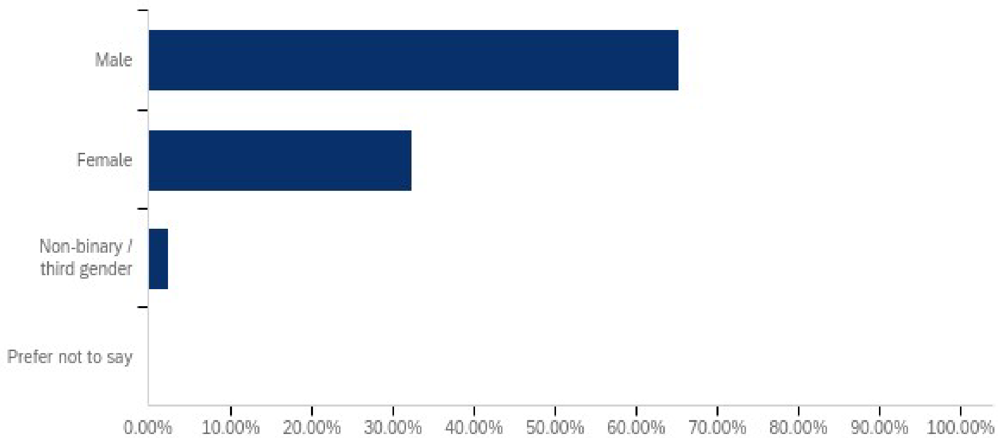


Figure 1. Distribution by gender

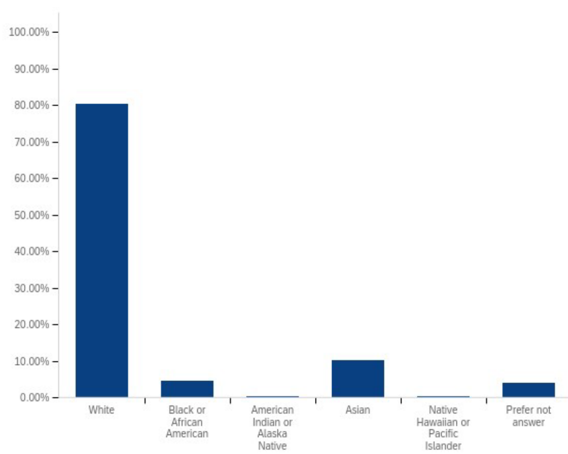


Figure 2. Distribution by ethnic background

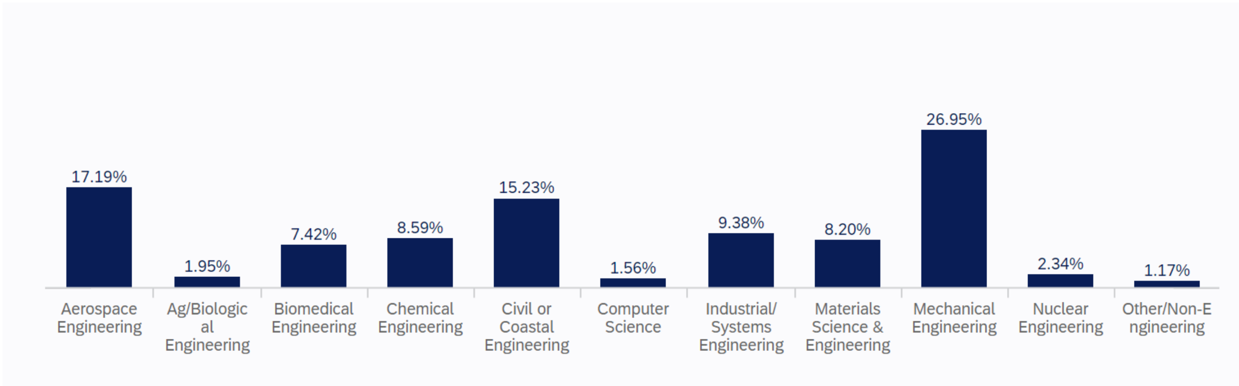


Figure 3. Distribution by major

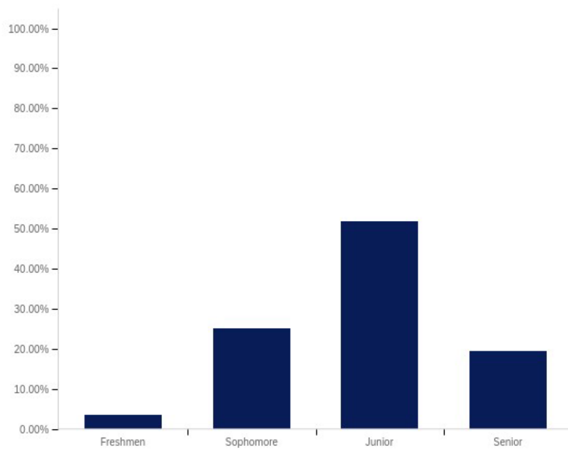


Figure 4. Distribution by year of study

Results

Table 1 presents the percentage of respondents' agreement using a 5-point Likert scale (5 – strongly agree; 1- strongly disagree) to statements related to the exposure to semiconductors providing insights into the level of exposure and familiarity with semiconductor-related topics among the surveyed sample. The statements include various aspects such as educational experiences, activities, and sources of information regarding semiconductors. Similarly, Table 2 displays respondents' agreement using a 5-point Likert scale (5 – strongly agree; 1- strongly disagree) on motivation to engage in semiconductors-related activities, such as reading about semiconductors, investigating related fields of study, or considering career opportunities.

Table 1. Level of Exposure to Semiconductors

Question	Strongly disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Strongly agree	Total
Heard the term semiconductor	2.75%	2.75%	3.92%	23.92%	66.67%	255
Read something about semiconductors	7.84%	7.84%	10.20%	35.29%	38.82%	255
Watched a video about semiconductors	13.39%	12.60%	17.72%	30.31%	25.98%	254
Had one or more instructors talk about semiconductors in class	9.09%	11.86%	14.23%	33.60%	31.23%	253
Participated in an activity involving semiconductors (lab, project, etc)	23.92%	15.69%	17.65%	23.92%	18.82%	255
Taken at least one university class about semiconductors	32.55%	21.57%	19.61%	16.86%	9.41%	255

Table 2. Motivation for Semiconductors

Question	Strongly disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Strongly agree	Total
Read something about semiconductors	10.20%	16.86%	20.39%	36.08%	16.47%	255
Investigate fields of study in which I can learn more about semiconductors	14.90%	23.53%	26.67%	25.10%	9.80%	255
Take a class about semiconductors	20.00%	25.49%	32.16%	16.08%	6.27%	255
Pursue a career in the field of semiconductors	33.46%	26.38%	28.35%	7.87%	3.94%	254
Pursue a research opportunity in semiconductors	25.59%	27.56%	31.50%	12.20%	3.15%	254
Pursue an internship in semiconductors	26.27%	30.98%	27.84%	11.76%	3.14%	255

Before further data analysis, any respondent with missing responses to any question was excluded from the dataset. This reduced the number of responses to 253. Instead of looking at each statement individually, we utilized Cronbach's alpha, a widely used measure of internal consistency, to assess the reliability of both the exposure and motivation constructs. The calculated Cronbach's alpha for the exposure construct was 0.843, while for the motivation construct, it was 0.925**,** suggesting a high level of internal consistency [18]. This led us to find the mean of the items for each of the constructs, exposure and motivation, for each student to conduct further data analysis. Table 3, 4, and 5 show the mean values according to gender, academic standing, and majors respectively.

Table 3. Mean and Motivation Levels Regarding Semiconductor-Related Topics Across Gender

Gender	N	Exposure Mean	Motivation Mean
Female	83	3.62	2.57
Male	166	3.39	2.66
Non-binary	6	4.19	3.22

Table 4. Mean Exposure and Motivation Levels Across Academic Standing

Academic Standing	N	Exposure Mean	Motivation Mean
Freshmen	9	4.13	3.06
Sophomores	64	3.29	2.74
Juniors	132	3.40	2.66
Seniors	50	3.88	2.40

Table 5. Mean Exposure and Motivation Levels Across Engineering Majors

	Majors	N	Exposure Mean	Motivation Mean
1	Aerospace Engineering	44	3.32	2.37
2	Biological Engineering	5	3.2	2.93
3	Biomedical Engineering	19	3.34	2.82
4	Chemical Engineering	22	3.61	2.79
5	Civil Engineering	39	3.39	2.07
6	Computer Science	4	4.12	2.79
9	Industrial/Systems Engineering	24	3.34	2.21
10	Materials Science & Engineering	21	4.26	3.69
11	Mechanical Engineering	68	3.41	2.86
12	Nuclear Engineering	6	3.69	2.5
14	Other/non-engineering	3	3.77	2.33

*Some majors were not represented in the sample (7,8, and 13)

Students in this multidisciplinary electrical engineering course demonstrated varying exposure to semiconductors. While these results are anticipated, they provide evidence for why it is important to introduce semiconductors to multiple disciplines, while also motivating students to consider how these technologies can be applied to their specific domains.

1) **There are differences in average exposure by gender while there are no statistically significant differences in motivation levels across genders.**

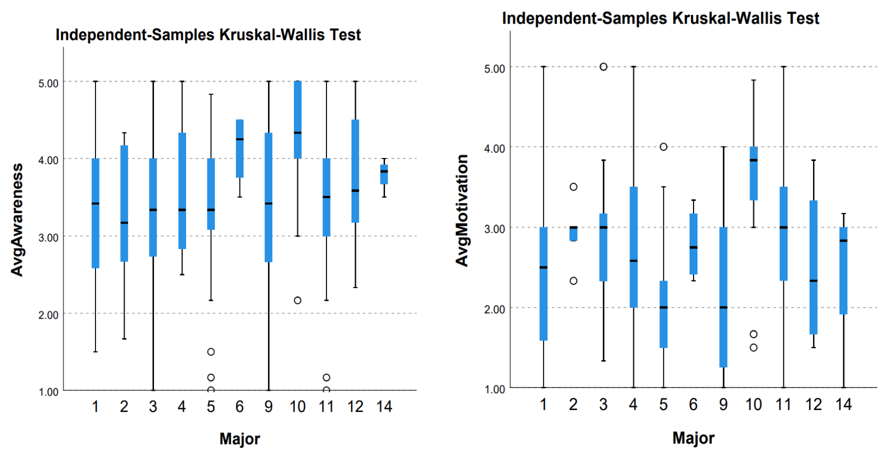
A Kruskal-Wallis test [19] was conducted to examine the differences in average exposure and motivation levels among three gender groups: female, male, and non-binary. The assumption of homogeneity of variances was violated, necessitating the use of the non-parametric Kruskal-Wallis test. The results for the exposure level revealed that the null hypothesis was rejected ($p < 0.5$), which means that the exposure level of at least one of the gender groups was significantly different than the other groups. Post-hoc pairwise comparisons with Bonferroni correction indicated that female reported significantly higher exposure levels compared to males ($p < 0.05$) while non-binary group reported significantly higher exposure levels compared to the male group ($p < 0.05$). There was no significant difference found in exposure level between the female and the non-binary group. Regarding the motivation levels, the Kruskal-Wallis test did not reveal any significant difference across gender groups, $p = 0.417$.

2) **There are differences in average exposure by academic standing year while there are no statistically significant differences in motivation levels across academic standing: i.e., freshmen, juniors, seniors, and sophomores.**

Similarly, a Kruskal-Wallis test was conducted to examine the differences in average motivation levels across four academic standing groups: freshmen, juniors, seniors, and sophomores. The test did not reveal a significant difference in motivation across the four groups, $p = 0.114$ suggesting an absence of statistically significant differences in motivation to engage with semiconductors-related topics among the four groups. Finally, the results revealed a significant difference in exposure levels in at least one of the academic standing groups among the four academic standing groups, $p < 0.05$. Post-hoc pairwise comparisons with Bonferroni correction indicated that seniors and first-year students reported significantly higher exposure levels than sophomores and juniors.

3) **There are statistically significant differences in average exposure by major and in motivation levels across engineering majors.**

To assess the exposure and motivation levels across various engineering majors, non-parametric Kruskal-Wallis tests were also conducted. The test revealed a significant difference in both exposure and motivation levels in at least one of the majors among all the engineering majors. Subsequent pairwise comparisons were conducted using Bonferroni correction to identify specific differences between majors, which indicated that Materials Science students reported significantly higher exposure and motivation levels than students from the other majors (Aerospace, Biological, Biomedical, Chemical, Civil, Industrial, Mechanical, and Nuclear; $p < 0.05$). Figure 5 shows the comparison of exposure and motivation levels across the engineering majors.



	Majors
1	Aerospace Engineering
2	Biological Engineering
3	Biomedical Engineering
4	Chemical Engineering
5	Civil Engineering
6	Computer Science
9	Industrial/Systems Engineering
10	Materials Science & Engineering
11	Mechanical Engineering
12	Nuclear Engineering
14	Other/Non-Engineering

Figure 5. Results of exposure and motivation levels across engineering majors.

Discussion

The findings of the present study are in line with initial expectations, highlighting both opportunities for improvement in engineering education and the need to foster awareness and understanding of semiconductor-related topics among students. The data reveal that while more than 66% of respondents have heard about semiconductors, only 9.41% have taken at least one university class on the subject, and 18.82% have participated in activities related to semiconductors. This result suggests a potential area for curriculum enhancement in engineering education. Keeping in mind that 72% of students taking the class are juniors and senior students, there is an opportunity to develop and expand semiconductor-related coursework to ensure a more comprehensive educational experience for students.

While the finding of higher exposure levels among females to semiconductors-related topics may seem unexpected given historical trends, it could be attributed to a combination of supportive educational initiatives, personal interests, and positive learning environments that promote gender diversity and inclusivity in STEM fields. The significant difference in exposure levels among freshmen and juniors and sophomores may be attributed to the small sample size of freshmen, which represents a limitation of this dataset. On the other hand, the significant variation in exposure levels among seniors and juniors and sophomores is not unexpected. This finding suggests there may be room for improvement in providing students with early exposure opportunities to semiconductor-related topics in the curriculum.

The comparatively lower value for the average motivation across gender, academic standing, and majors and the absence of significant differences in motivation levels across gender and academic standing groups suggest that current educational approaches may not adequately address the diverse needs and interest of students that could improve students' motivation towards semiconductors-related topics. There is an opportunity to tailor curriculum content to enhance student engagement and motivation for semiconductors-related careers. This could be done by adjusting the existing curriculum with real-world applications, hands-on activities, and project-based work with semiconductor-related topics. For example, Nelson, et.al, (2017) demonstrated how to create simulations to aid students learning about semiconductors.

As it might be anticipated, materials science students exhibited a higher level of exposure to and motivation towards semiconductor-related topics in comparison to their peers from other majors. This finding aligns with the theoretical foundations of materials science education, which often places a particular emphasis on semiconductor materials and their applications. Furthermore, these results highlight the importance of integrating semiconductor concepts into the broader engineering curriculum, thereby ensuring that students from diverse majors have equitable access to foundational knowledge and opportunities for specialization. Such initiatives not only enrich the educational experience but also equip students with the interdisciplinary skills and competencies essential for addressing complex real-world challenges in semiconductor technology and beyond.

Conclusions

This study aimed to address the challenges in attracting students to the semiconductor industry by providing specific insights and data-driven analysis regarding students' exposure to and motivation for semiconductor-related topics within the context of a multidisciplinary engineering course. Through this analysis, we have identified the current level of exposure and motivation among students, laying the groundwork for targeted interventions and curriculum enhancements.

Moving forward, it would be valuable for future research to explore whether exposure to a well-designed semiconductor module influences the motivation of non-electrical engineering students towards semiconductors and how this exposure may impact their career intentions. By continuing to investigate these areas, we can further refine educational strategies and develop initiatives to better engage students and prepare them for their involvement in the semiconductor industry.

In summary, this study contributes to the ongoing efforts to address workforce challenges in the semiconductor industry by providing actionable insights and suggesting avenues for future research and intervention. By leveraging these findings, educators, policymakers, and industry stakeholders can work collaboratively to strengthen the talent pipeline and drive innovation in the semiconductor sector.

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