2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #53365

Investigating how Internship Participation Influences the Career Direction of Undergraduate Biomedical Engineering Students

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Abstract

Undergraduate internships and co-operative education experiences play a critical role in shaping students' post-graduation career decisions by enhancing their understanding of professional roles and career trajectories. As biomedical engineering (BME) continues to expand across academia, industry, healthcare, and government sectors, it is important to explore how experiential learning influences students' career pathways. This study examined how participation in undergraduate BME internships impacted students' subsequent career decisions, and investigated at what point such experiences may be most beneficial within the curriculum. Building on a ten-year retrospective outcomes analysis, longitudinal data from 226 former undergraduate BME students at a Hispanic Serving Institution (HSI) were analyzed from Spring 2014 to Spring 2024. The data collection methodology was based on publicly available LinkedIn information, focusing on employment after graduation. Data suggests that internships did not significantly influence biomedical engineering students' post-graduation career streams or geographic employment outcomes, instead serving primarily as a means of broadening professional exposure, with participation trends largely shaped by external economic and societal factors rather than direct effects on employment trajectories

Introduction

Internships are critical and highly valued experiential learning opportunities in the engineering field, particularly as the job market has become increasingly competitive [1, 2]. Participation in internships has also been shown to increase students' confidence when making career decisions, as it helps clarify their career interests and often smooths their transition from academia into the workforce by providing real-world experiences [1]. This exposure is especially important in the biomedical engineering field because employers increasingly seek graduates with prior experience and a very strong foundational background in engineering concepts, enabling them to contribute to the workforce immediately [1-5].

Prior research has examined the relationship between internships and early career outcomes in engineering and STEM fields, with mixed findings. Studies have shown that experiential learning opportunities such as internships and co-ops can enhance job readiness, professional identity development, and initial employment prospects [6,7]. Other work has emphasized the role of internships in strengthening professional networks and facilitating smoother school-to-work transitions [8]. Within engineering education, experiential learning has also been linked to improved career clarity and persistence in the field [9]. However, less is known about how internship participation influences specific career streams or geographic outcomes within

biomedical engineering. The present study contributes to this literature by examining long-term employment trajectories rather than immediate job placement and by situating outcomes within a regional and institutional context.

This study examined the post-graduation outcomes of students who completed a bachelor's degree in biomedical engineering at a public HSI in the state of Texas, a region with an established biomedical engineering sector and a growing demand for biomedical engineers [10]. As of 2023, Texas ranks third in the nation for employment of biomedical engineers, with a projected employment growth of 5% from 2024 to 2034 [10]. As these employment opportunities continue to grow, it becomes increasingly important to understand how undergraduate educational experiences influence post-graduation employment outcomes.

To examine these relationships within this context, data for this analysis were drawn from BME alumni who formerly attended the institution, using primarily publicly available LinkedIn profiles. The BME department had intentionally incorporated applied learning into its curriculum by requiring all biomedical engineering undergraduates to complete a core course: Biomedical Engineering Technology and Product Development (Tech & Dev). The goal of this course is to introduce students to current biomedical technologies, the process of commercialization, and customer-informed product design with emphasis on the pathways to regulatory approval and commercial implementation of novel medical devices. In addition, some students choose to gain real-world experience by applying the information learned in Tech & Dev through a specialized biomedical internship (i.e., BME internship) elective, which allows them to explore the biomedical industry or biomedical research experiences external to the university they attend and to leverage that knowledge at a location of their choosing. This study examined how participation in both Tech & Dev and the BME internship course may influence students' post-graduation activities. Specifically, this research study is guided by the following research question:

How and in what ways does engagement in undergraduate internship experiences influence biomedical engineering students' career decisions?

To answer this question, we use the professional career development app LinkedIn [11] to investigate whether these combined experiential learning opportunities drive students toward certain career domains and whether they influence their geographic location after graduation.

Methodology

Study Design and Sample Selection

This study examined the career trajectories of Bachelor of Science in Biomedical Engineering graduates at an HSI over 10 years, from Spring 2014 to Spring 2024. A total of 226 alumni were included in this study, based on the following inclusion criteria: (1) Enrollment in the Tech &

Dev course between Spring 2014 and Spring 2024, and (2) a publicly accessible LinkedIn profile with employment listed following undergraduate graduation. Although the study was conducted at a Hispanic-Serving Institution, demographic variables were not included in the analysis because the data were collected from publicly available LinkedIn profiles, and no assumptions about students' identities were made in order to preserve accuracy and avoid misclassification.

In addition to Tech & Dev being a mandatory course in the biomedical engineering discipline, all enrolled students were encouraged to create a LinkedIn profile, ensuring 100% availability for the two cohorts listed above. Moreover, Tech & Dev introduced students to different career pathways in biomedical engineering, meaning all students had equal exposure and guidance. Furthermore, instructional periods were devoted to preparing biomedical engineering-specific resumes and cover letters, highlighting resources to learn available skills. Lastly, this study was deemed exempt from Institutional Review Board (IRB) review because all data were obtained from publicly available sources and did not involve direct interaction with participants or access to private, identifiable information.

For the purposes of this study, internships were defined as structured, time-bound experiential learning positions undertaken during undergraduate study, including industry internships, clinical research opportunities in hospitals, government or federal/military biomedical placements, and Research Experiences for Undergraduates (REU) programs. Ongoing academic employment during the academic year (e.g., laboratory research assistant positions) was not classified as an internship.

Manual Data Recording

Alumni were manually searched for on LinkedIn. For each alumnus, their employment information was recorded and classified into one of five fields outlined in **Table 1**.

Table 1: This table outlines the descriptions of employment and internship classifications.

Field of Work	**Employment or Internship Description**
Industry	Employment or internship in engineering or technology companies.
Federal	Employment or internship by agencies of the federal government or military
Academic	Employment or internship at a university or continued higher education
Medical	Employment or internship at hospitals, clinics, or other healthcare facilities

Geographic employment outcomes were also recorded and categorized as local, not local, or remote, as outlined in **Table 2**. Alumni were categorized based on their most recent reported full-time position. While some individuals may have transitioned between career fields over time, this study focused on the first post-graduation role rather than the terminal or current career classification. While we acknowledge that this approach may obscure later transitions, one of the objectives was to look at the impact of the internship on immediate professional orientation or

predisposition and future work is intended to further look into those later transitions after graduation.

Table 2: This table outlines the descriptions of geographic employment outcomes.

Location	Description
Local	Employment within economic region of undergraduate degree institution.
Not- Local	Employment that is beyond the local region.
Remote	Entirely remote positions.

Data Analysis

Table 3: This table outlines the distribution of alumni.

Classification	Description
Intern (Experimental Group)	An alumnus that completed an internship through a BME internship course and completed Tech & Dev (n= 113).
Non-Intern (Control Group)	An alumnus that did not complete an internship through a BME internship course. Alumni from the remaining students who were enrolled in Tech & Dev between 2014 to 2024 and did not complete an internship were randomly selected (n= 113).

Tech & Dev was used to select the alumni for the control group because our prior work [12] demonstrated that most students reported an increased preparedness for capstone design after finishing the course, suggesting they were all equally prepared for post-graduation careers at that time. Capstone Design is a representative of an entry-level biomedical industry position post-graduation, as students collaborate with local biomedical engineering companies to design and potentially commercialize a product. Also, because the prevailing economic conditions greatly effect employment trends, to account for such differences across graduation years, the number of alumni per year was equalized between interns and non-interns, classification explained in **Table 3**, and we separately note the fraction of each graduating cohort that participated in an external internship each year to look at year-over-year trends. This data is presented in **Table 4**.

Results

Figure 1 shows the percentages of interns and non-interns outlined in **Table 4** over the ten-year period, with the lowest percentage of students participating in an internship being in 2014 (the first ever cohort of biomedical engineering graduates from the institution), followed by 2023. This is likely due to the prevailing economic factors at the time. There is also a noticeable increase in the number of students participating in internships between 2019 and 2021. This increase coincides with the beginning of the COVID-19 pandemic, which has been

acknowledged to cause many changes in behavior in the biomedical industry and led to a local glut of federal and industry internship opportunities, and multiple fully online academic internship programs [13,14].

Table 4: Students Enrolled per Year of Tech & Dev and sub-sets of Interns and Non-Interns

Year Enrolled	Enrolled Students Tech & Dev [A]	Intern Students [B]	Non-Intern Students [C] -> [A-B]	Random subset Not Intern [D] -> [B=D]	Percentage of Interns [E -> B/A x 100]	Percentage of non-interns [F -> 100-E]
2014	21	1	20	1	4.76	95.24
2015	32	8	24	8	25.00	75.00
2016	46	18	28	18	39.13	60.87
2017	38	12	26	12	31.58	68.42
2018	29	8	21	8	27.59	72.41
2019	38	15	23	15	39.47	60.53
2020	45	8	37	8	17.78	82.22
2021	45	19	26	19	42.22	57.78
2022	59	12	47	12	20.34	79.66
2023	55	8	47	8	14.55	85.45
2024	50	4	46	4	8.00	92.00
Total	**458**	**113**	**345**	**113**		

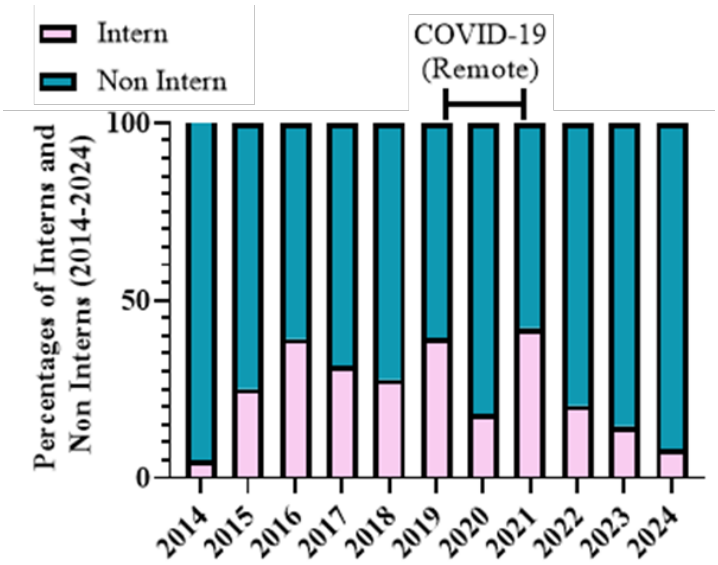

Figure 1: Percentages of students who completed an internship that were enrolled in Tech & Dev per year.

To further examine the relationship between internship experiences and post-graduation outcomes, a Sankey diagram (**Figure 2**) was used to visualize the career streams following internship participation to post graduation employment and the career streams of alumni that did not complete an internship. This figure demonstrates that more students pursue careers in industry regardless of their internship experience. However, it is closely followed by alumni who pursue a graduate degree or positions in higher education. This is likely due to potential additional education requirements needed to pursue their desired position, such as becoming a professor. Additionally, economic conditions should be considered, including whether there were a limited number of entry-level biomedical engineering industry employment opportunities, because that could also influence decisions about pursuing higher education. Following the analysis of career trajectories post-internship, the groups were compared to determine whether there was a correlation between the internship and no-internship groups. A Fisher's with Monte Carlo simulation test showed no statistically significant association (p-value = 0.6897) between occupational outcomes and internship participation. This was further confirmed by an effect size analysis (by Cramer's V test), which indicated a negligible association. This research also investigated whether alumni pursue careers at the companies where they interned, thereby influencing their career streams. Only 9 students remained at the same company/university where they interned (**Figure 3**) and, given the low volume, we did not anticipate this influencing their final career direction.

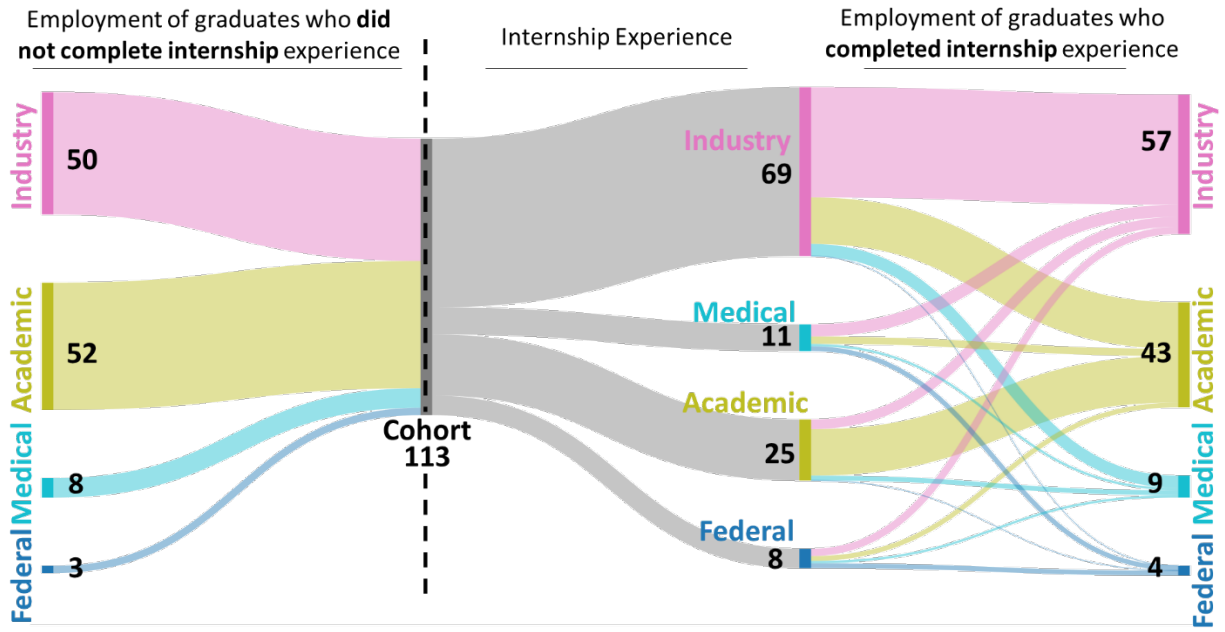

Figure 2: Career streams of alumni post-graduation, starting with the distribution among the matched non-intern students, then the impact (or lack there-of) of the internship stream on the career choices of alumni post-graduation who participated in the voluntary internship.

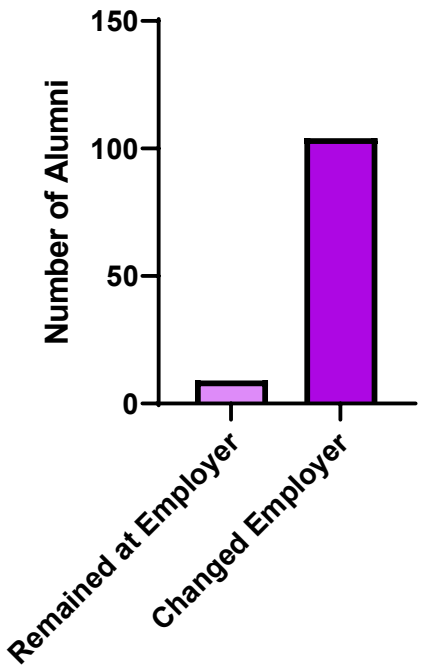

Figure 3: The number of alumni that remained at the same institution after completion of the BME Internship course relative to those that changed institution for their employment.

The geographic location of alumni career outcomes is shown in **Figure 4**. Regardless of internship completion, both groups had a similar outcome: most students did not stay locally, and remote positions were not common. A Fisher's with Monte Carlo simulation test showed no statistically significant association (p-value = 0.8122) between occupational outcomes and internship participation. This was further confirmed by an effect size analysis (Cramer's V), which indicated a negligible association. Additionally, this study also took the geographic location of where alumni completed their internships into account. While comparable, most students did not remain in the same location as they interned. This further confirms that internship completion may not be the strongest driving factor for alumni to choose post-graduation career locations.

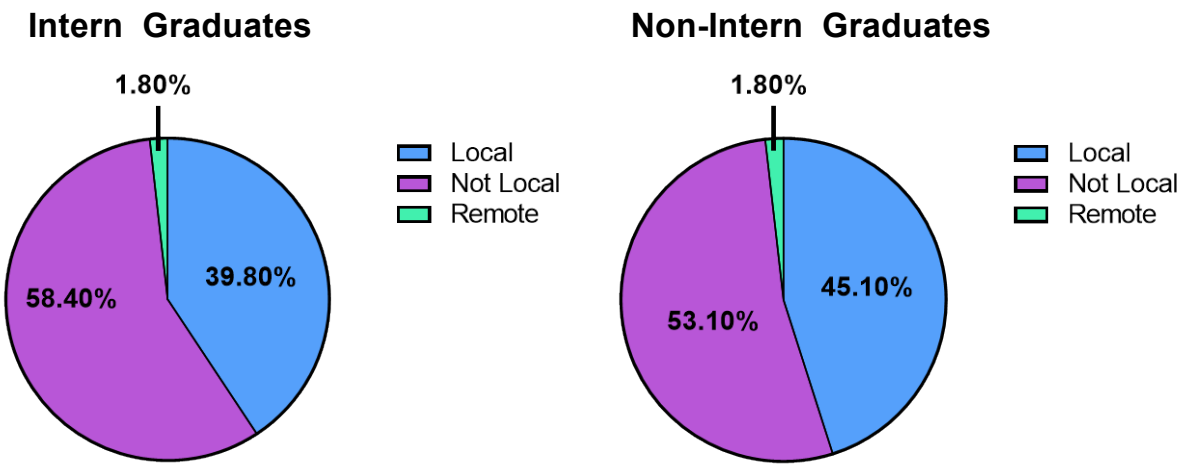

Figure 4: Geography of employment for graduates as a function of pursuing internship

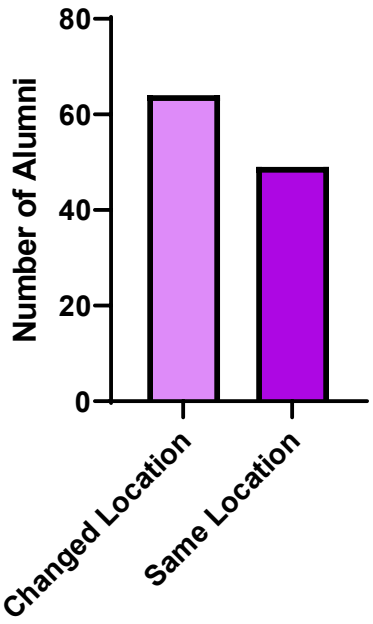

Figure 5: Geographic Employment Outcomes In Relation to Internship

Discussion and Conclusion

This study provides insight into how internships influence the employment outcomes for biomedical engineering students following graduation. This is best shown within the Sankey diagram (**Figure 2**) and **Figure 3**, which clearly demonstrate that regardless of internship experiences, students pursue post-graduation employment career streams in a very similar manner to non-interns across cohorts. Interestingly, the stream in which the internship is pursued does not seem to significantly impact the future full-time employment stream. Given this information, it

suggests that internships might not be a key factor in terms of employment outcomes for biomedical engineering students following graduation, but rather a broadening of exposure to applied biomedical engineering. This was supported by statistical analysis, showing no statistically significant differences between internship and non-internship groups. However, it is possible that there is more to consider regarding the influence of internships. For instance, academic internships in a university laboratory sometimes led students to pursue further education, reflecting the possibility of students learning about additional qualifications required for careers in higher education or research.

Trends in internship participation over the ten-year period reveal the impact of broader economic and societal factors on experiential learning. Participation was lowest in 2014, likely due to lingering effects of the post-recession recovery and that being the first cohort of biomedical engineering students seeking internships in the region, which then led to the establishment of internship pipelines through agreements with local industry and professional exposure to national research experiences programs provided to students. In 2023, the ratio of interns was again lower, potentially reflecting post-pandemic disruptions or other economic pressures, as well as the largest enrolled class in the history of the biomedical program to that point, thirsting for in-person education. The sharp increase in participation between 2019 and 2021 coincides with the onset of the COVID-19 pandemic, which uniquely created multiple local internship opportunities in industry and federal government, all of which were short-term and rapid-response positions ideally suited for young trainees, as well as the conversion of many external academic research internship opportunities to fully remote during this period greatly increased participation[9]. These year-to-year trends highlight the vulnerability of experiential learning programs to external crises.

Moreover, internships appear to have a less influential role than anticipated when determining geographic employment outcomes. Most alumni, regardless of internship participation, did not remain local, and few held remote positions (**Figure 5**). This suggests that factors such as position availability, personal preferences, or professional networks may play a stronger role in geographic decisions than internships alone. However, the low prevalence of remote work emphasizes the continued importance of hands-on, location-based internship experiences in providing relevant skills and exposure. Also, the geographic analysis did not account for students' state of origin. It is possible that alumni returned to their home states following graduation, independent of internship participation. As such, geographic outcomes may also reflect personal or familial factors rather than internship influence alone.

Overall, these findings highlighted that external factors, including economic conditions and the requirements of further education, can mediate the influence of internships. Future work should examine how timing, duration, and type of internship further shape both career domain and geographic outcomes, as well as how economic fluctuations affect student participation in experiential learning opportunities. While short-term employment outcomes may more directly reflect internship influence, long-term outcomes capture sustained career pathways and professional mobility. We acknowledge that career shifts over time may attenuate the measurable

impact of internships, and future work could compare short-term and longitudinal outcomes to better isolate temporal effects.

Limitations

Several limitations should be considered when interpreting these findings. First, the study relied on publicly available LinkedIn profiles, which may not fully capture all graduates' employment outcomes; some alumni may not maintain updated profiles or may omit certain positions, leading to potential underrepresentation. Second, the analysis is limited to students who completed the Tech & Dev course at a single HSI, which may reduce generalizability to other institutions or regions. Third, the observational nature of this study precludes causal inferences; while associations between internship participation and career domain are not present, other unmeasured factors—such as personal motivation, faculty mentorship, or pre-existing networks—may also influence career trajectories. Moreover, a limitation of this study is that, although the alumni sample was drawn from a Hispanic-Serving Institution, demographic variables were not included in the analysis. Because the data were obtained from publicly available LinkedIn profiles, no assumptions were made about students' identities in order to preserve accuracy and avoid misclassification. As a result, the study cannot examine how post-graduation outcomes may differ across demographic groups, nor can it assess whether institutional context interacts with identity-related factors in shaping employment trajectories. Finally, the study does not account for the quality, duration, or intensity of internships, which could differentially affect career outcomes.

Future Work

Future research should expand to multiple institutions and include a broader range of experiential learning opportunities to enhance generalizability. Incorporating surveys or interviews with alumni could provide richer qualitative insights into their satisfaction with their internships and how internships shape career decisions and geographic choices. Longitudinal studies examining timing, type, and duration of internships could clarify optimal points for integrating experiential learning into the curriculum. Additionally, future work could investigate how economic fluctuations, remote work trends, and industry demand influence both internship participation and post-graduation outcomes. Also, future work should incorporate verified demographic data to examine how identity-related factors may intersect with institutional context to influence post-graduation employment outcomes. Moreover, this study did not assess the qualitative nature or perceived quality of internship experiences. Prior research suggests that mentorship quality, task relevance, and student engagement may significantly influence long-term outcomes. Because the present analysis relied on publicly available data, experiential depth and satisfaction could not be evaluated. Future research incorporating survey or interview data could examine how internship quality mediates career trajectories. Finally, studies could explore interventions or advising strategies to help students maximize the impact of internship experiences on career trajectory and professional growth.

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