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The Influence on Engineering Industry Career Paths of Specific Undergraduate Student Experiences and Activities

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Introduction

Background

The options of career pathways for graduates of engineering programs have continued to shift over the past years and decades [1]. Despite these broader options for engineering graduates, much research in engineering education is still focused on binary career paths of "Technical" and "Managerial" paths, as well as "Hybrid" or other career paths [2], [3], [4], [5], [6] . Engineering graduates are continuously pursuing more diverse career options once they complete their degrees and the engineering undergraduate student experience is now doing more than preparing students for traditional technical engineering careers. The engineering undergraduate student experience now encompasses much more than taking technical courses, and includes aspects such as engineering student clubs, co-ops and internships, research opportunities and more [2], [6], [7], [8]. These experiential learning opportunities can have an influence on the types of career paths that engineering graduates choose to pursue after they complete their degrees.

Positionality Statement

I am a Black woman, born and raised in the Caribbean, who immigrated to Canada to pursue an undergraduate degree in chemical engineering. During my undergraduate degree I was involved in extra-curricular and co-curricular activities that I feel have influenced my career paths. Upon completion of my undergraduate degree, I have now gone on to have a varied career which so far has included completed a master's program in engineering, working in a more traditional engineering field within oil & gas in Alberta, becoming a wife and mother, gaining my P.Eng license and PMP, starting a non-profit organization and various other social enterprises, pivoting to work in higher education and now coming back to school to pursue a PhD.

Motivation and Research Purpose

The motivation behind this research is to attempt to quantify and validate how certain undergraduate activities and experiences influence engineering career pathways beyond the traditional binary engineering career paths. This was influenced by my own positionality as someone who would not be considered to be fully on a traditional "Technical" or "Managerial" career path, but also felt as though specific activities in my undergraduate student experience influenced my career pathway.

This research seeks to answer the following questions: (1) Which aspects of the engineering undergraduate student experience are most influential for specific career pathways that engineering graduates pursue after their degree? (2) For engineering graduates that took specific career paths, which types of undergraduate activities were they most likely to participate in?

Design & Method

This research used Social Cognitive Career Theory (SCCT) [9] as the conceptual framework. SCCT posits that learning experiences are influenced by person inputs and contextual factors, these learning experiences can influence self efficacy and outcome expectancies as well as interest, which in turn influence career goals and career choices. Using SCCT as a framework, a survey was designed based on PEARS (Pathways of Engineering Alumni Research Survey) [10], which asked questions related to participation in specific undergraduate student activities and their influence on career. The survey was distributed to engineering graduates who completed their degrees at least 5 years prior. The survey was modified and respondents were asked to provide their LinkedIn profiles. LinkedIn profiles were analyzed using a method similar to the 10,000 PhDs project [11] to determine the career pathways of the engineering graduates. Using the LinkedIn data, pathways were classified into 6 categories: Academic, Boundary Spanner, Entrepreneur, Managerial, Technical Specialist, and Invisible Engineer [12], [13]. These pathways were loosely defined as follows:

- Technical Specialist: A career pathway characterized by primarily technical roles/occupations in engineering intensive industries
- Managerial: A career pathway characterized by roles of increasing seniority or leadership over time within engineering intensive industries
- Boundary Spanner: A career pathway characterized by a combination of technical and non-technical roles, typically primarily engineering-conpar roles, and typically still within engineering intensive industries
- Entrepreneur: A career pathway characterized by roles focused on founding a company or organization, or standing up a department within an organization, and continuing in an entrepreneurial role for a number of years
- Invisible Engineer: A career pathway characterized by primarily by non-technical or engineering-conpar roles outside of engineering intensive industries
- Academic: A career pathway characterized primarily by academic roles focused on teaching or research, typically in higher education industry

The survey was followed by interviews with engineering graduates from the various career pathways to add more insight to how the undergraduate activities influenced their career pathway. Survey respondents were asked to indicate their interest in

Results & Discussion

Findings

A total of 151 respondents provided their LinkedIn profiles. Based on the LinkedIn profile data the respondents' career pathways were broken down as follows: 12 Academic, 21 Boundary

Spanner, 15 Entrepreneur, 14 Invisible Engineer, 24 Managerial, 64 Technical Specialist. Figure 1 below shows the breakdown of respondents by their career path classification.

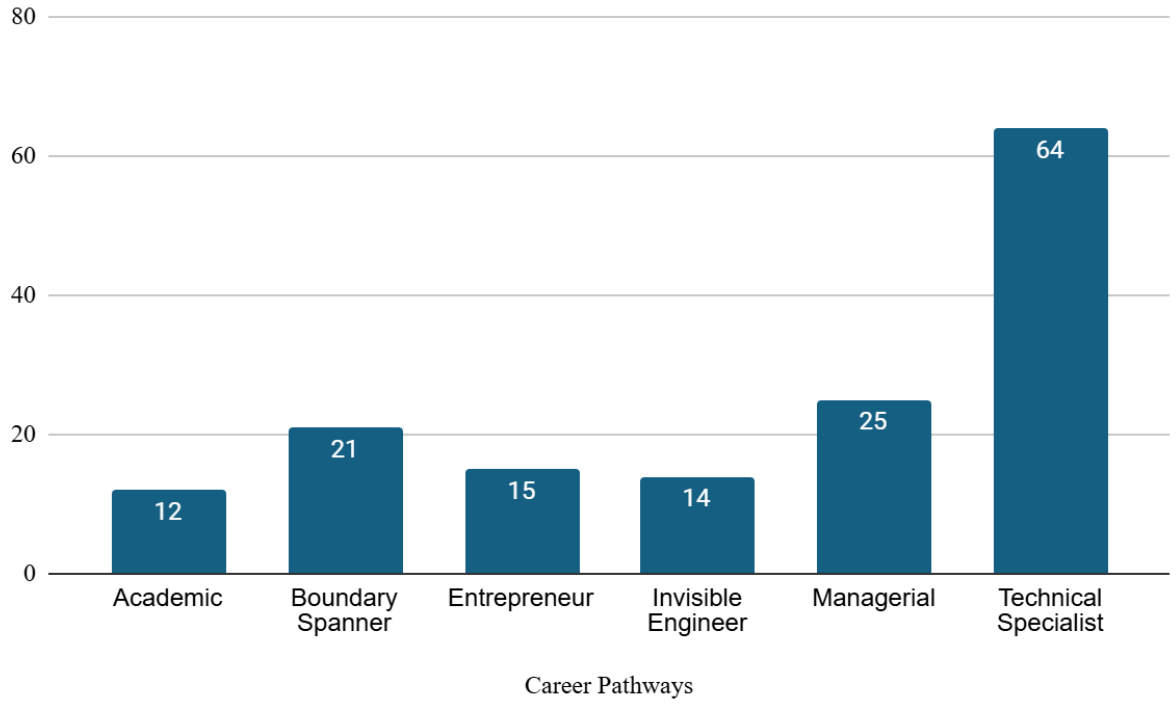

Figure 1. Breakdown of respondents by career pathway

Table 1 below shows the survey options for undergraduate activities. For each of those activities survey respondents were asked how influential they were on their career path. This question was phrased as "How influential has the following experiences from your undergraduate degree been on your career choices?"

Table 1. Survey options for undergraduate activities

Response	Short-form
Conduct research with a faculty member	Research
Work in an engineering environment as an intern/co-op	Co-op Intern
Participate in a work-study program (non-engineering role or non-research)	Work-Study

Work on technical team-based projects as part of a course	Technical Team Project
Participate in activities hosted by engineering-related student clubs, groups, or community service	Eng Club
Serve as a leader in an engineering student organization	Eng Leader
Participate in activities by student clubs, groups, or community service outside of engineering	Non-Eng Club
Serve as a leader in a non-engineering student organization	Non-Eng Leader
Participate in a study abroad program	Study Abroad
Participate in an incubator or entrepreneurship program	Entrepreneurship
Utilize academic/career advising services	Academic/Career
Participate in a formal mentoring program	Mentor

The responses to this question were matched to the LinkedIn data that was used to categorize career paths. This allowed for analysis of the responses to this question by the career path type of the respondent. Figure 2 below shows the percentage of respondents from each career path type that chose a certain undergraduate activity as being influential to their career.

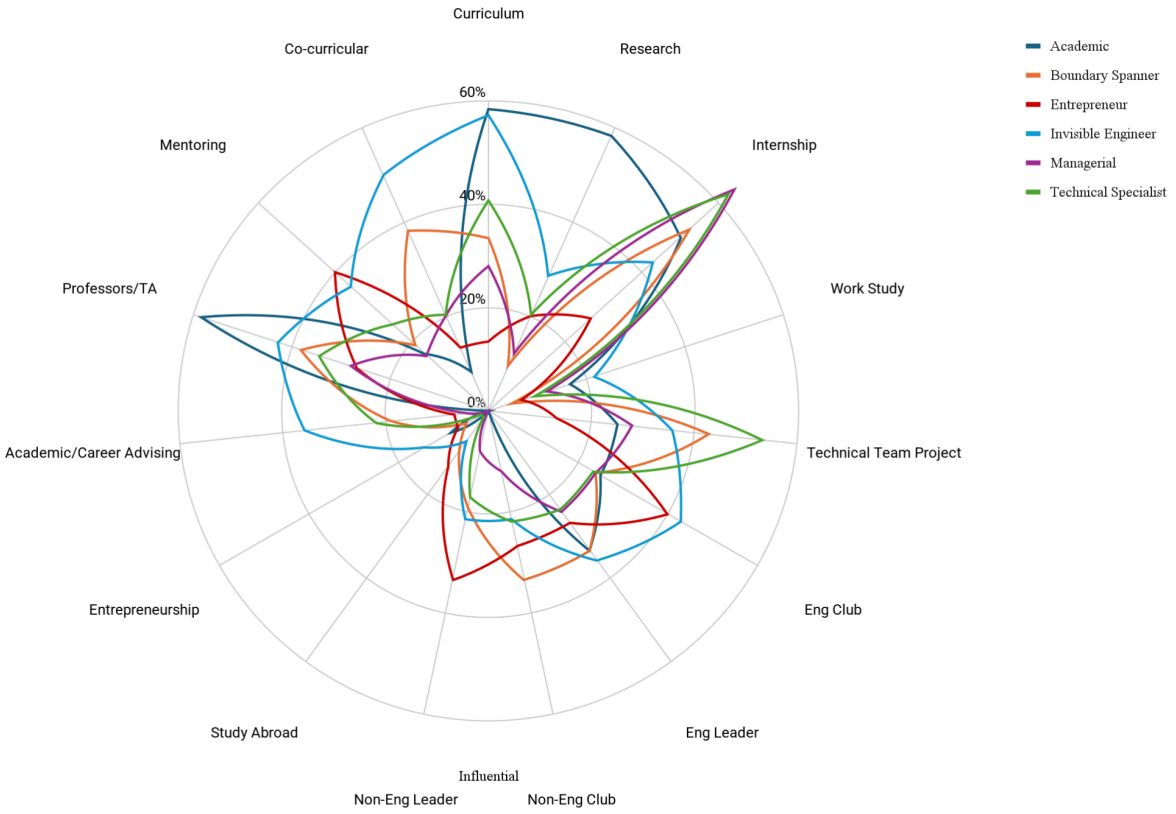

Figure 2.

Figure 2. Influential Activities for each Career Path

In the survey, engineering graduates were also asked to reflect on their undergraduate student experience and identify which activities they had participated in. This question was framed as "When you were an undergraduate engineering student, did you participate in any of the following (select all that apply)?"

The responses to this question were also matched to the LinkedIn data that was used to categorize career paths. It is assumed that all respondents participated in the engineering curriculum and had some sort of interaction with their professors/TAs. Figure 3 below shows the percentage of respondents from each career path type that responded that they participated in each specific undergraduate activity.

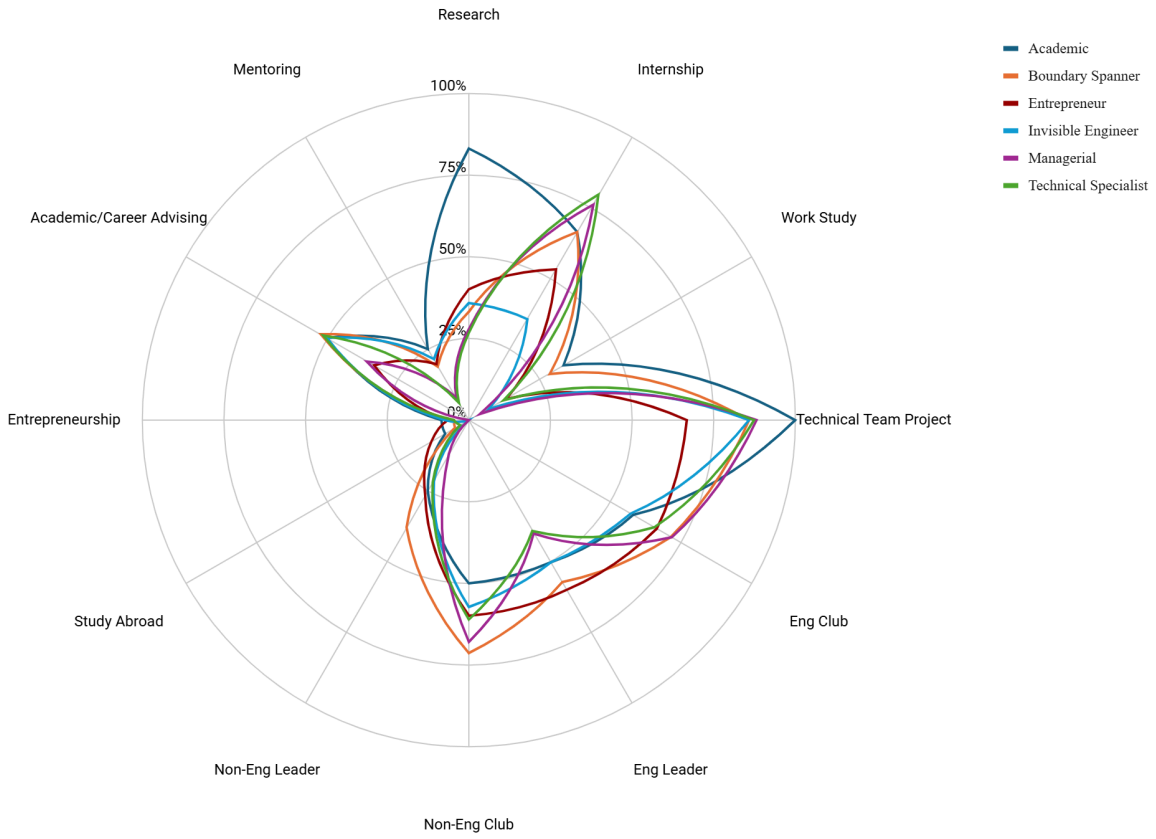

Figure 3. Activity Participation for each Career Path

Academic Career Path

Those who took Academic career paths were statistically more likely to participate in Research (83%) than any other career path ($\chi 2$ (df=1, N=52) = 5.29, p>.05). Academic career paths were also most frequently cited as participating in technical team projects, with 100% of those categorized as being in academic career participating in some sort of technical team project. The activities most commonly cited by those who took Academic career paths as influential were Research, Curriculum and Interactions with Professors; with 58% of those categorized as being in Academic Career Paths citing those activities as influential. The Figure below shows the influential and participation responses for engineering graduates in Academic career paths.

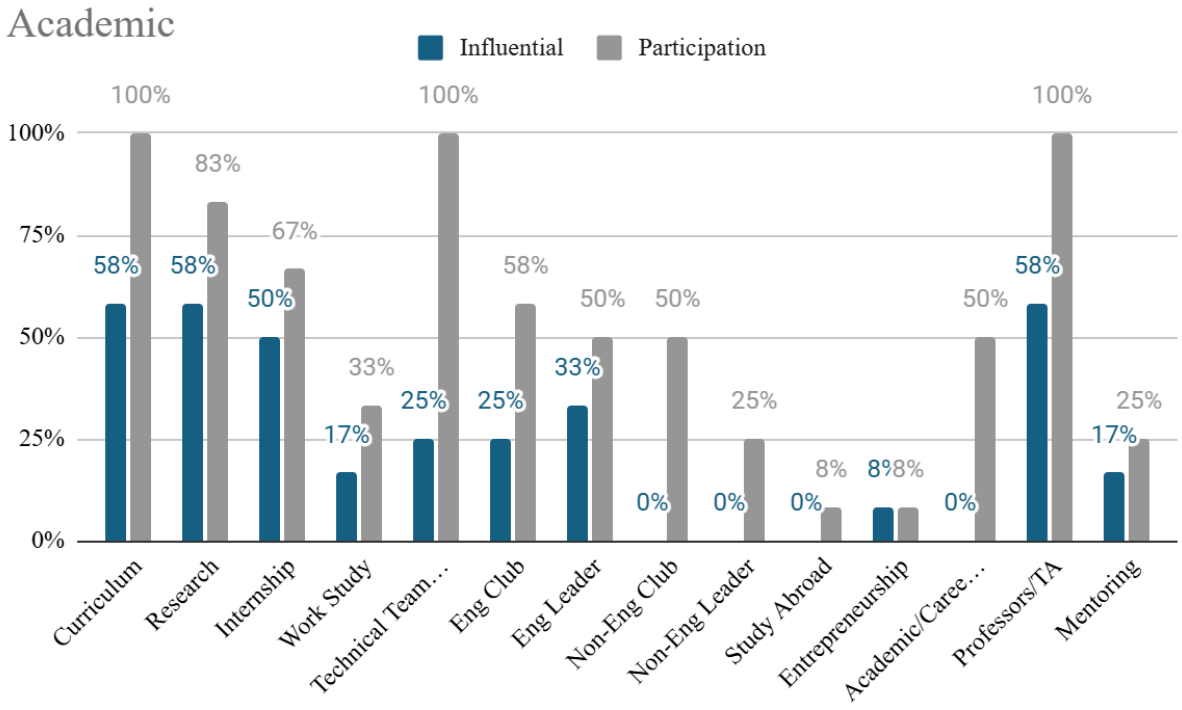

Figure 4. Influential Activities and Participation Rates for Academic Career Paths

Interviewees that took Academic career paths, or went on to pursue research based graduate studies, all mentioned the influence of undergraduate research activities.

> "I got an undergrad research award. And so then I did my summer research in my third year with, with [undergraduate supervisor], who is cross appointed with materials and, and biomaterials…then that's why I did biomed for my PhD and all that was I'm starting to get closer and closer to this idea of we actually do like health care."

> "In my fourth year, the pivotal experience there was doing my undergrad thesis…. in many ways, I think that opened up this door of curiosity of like, oh, I'm seeing something through these conversations with people, and I can actually try to pursue trying to understand what's happening here…. and I think that really sparked an interest in research for me. So that informed me pursuing a master's right after undergrad."

Boundary Spanner Career Path

Those who took Boundary Spanner career paths had relatively high/moderate participation in many different activities including technical team projects (86%), engineering clubs (71%),

non-engineering clubs (71%) and internships (68%). Of all of the career pathways, they most commonly participated in non-engineering clubs. The activity most commonly cited by Boundary Spanners as being influential were Internships (52%) followed by technical team projects (43%). The Figure below shows the influential and participation responses for engineering graduates in Boundary Spanner career paths.

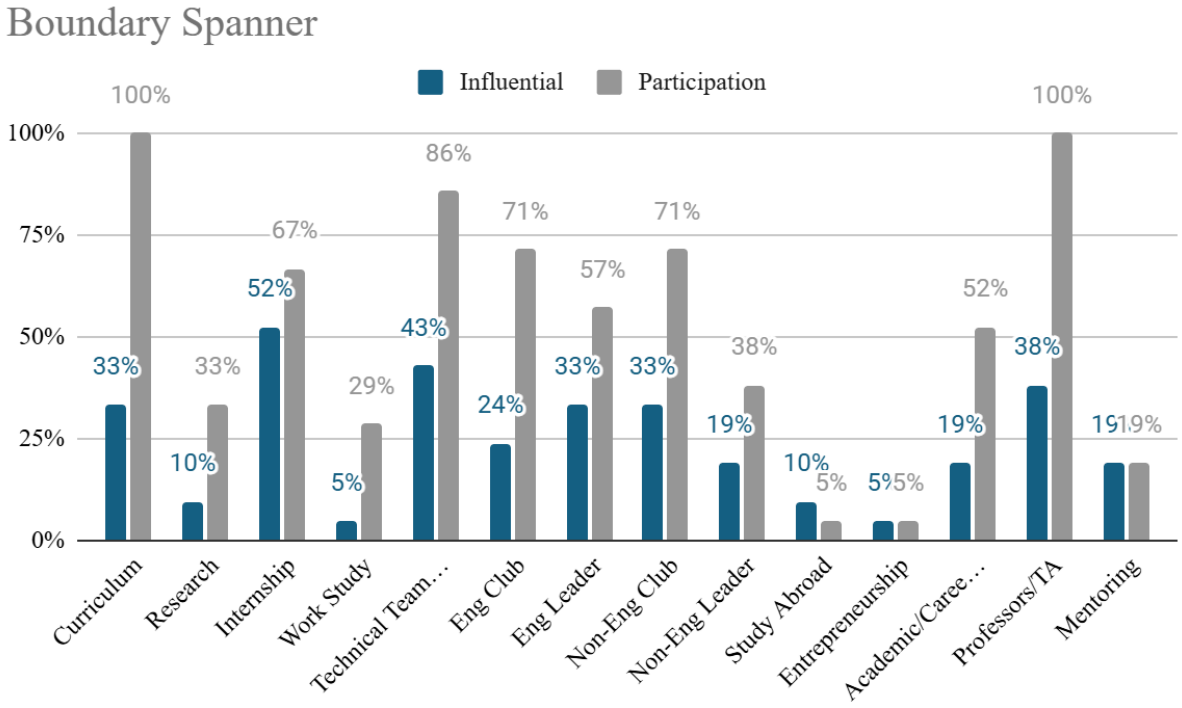

Figure 5. Influential Activities and Participation Rates for Boundary Spanner Career Paths

The below quotes highlight how technical team projects and internships influenced the Boundary Spanner career path for an engineering graduate.

> "I think it was the first time for me really to just really get into that project mindset and the reason why I said it kicks started a lot of things is because now, I mean, I ended up as a business analyst for like a year and a half, and then got became a project engineer, and a project manager and then a consultant who runs projects"

> "I think because of the co-op, I'm used to always changing jobs and doing different things. So that aligns with me too. So it's like you're not staying in the same role for so many years."

Entrepreneur Career Path

Overall, those in Entrepreneurial career paths seemed to have relatively low participation in many activities when compared to other career paths. However, for those who took Entrepreneur career paths, participation in Study Abroad (13%) was more common and cited as being influential (13%) more frequently than other career paths. Because participation in study abroad was so low, it wasn't possible to measure statistical significance. The Figure below shows the influential and participation responses for engineering graduates in Entrepreneurial career paths.

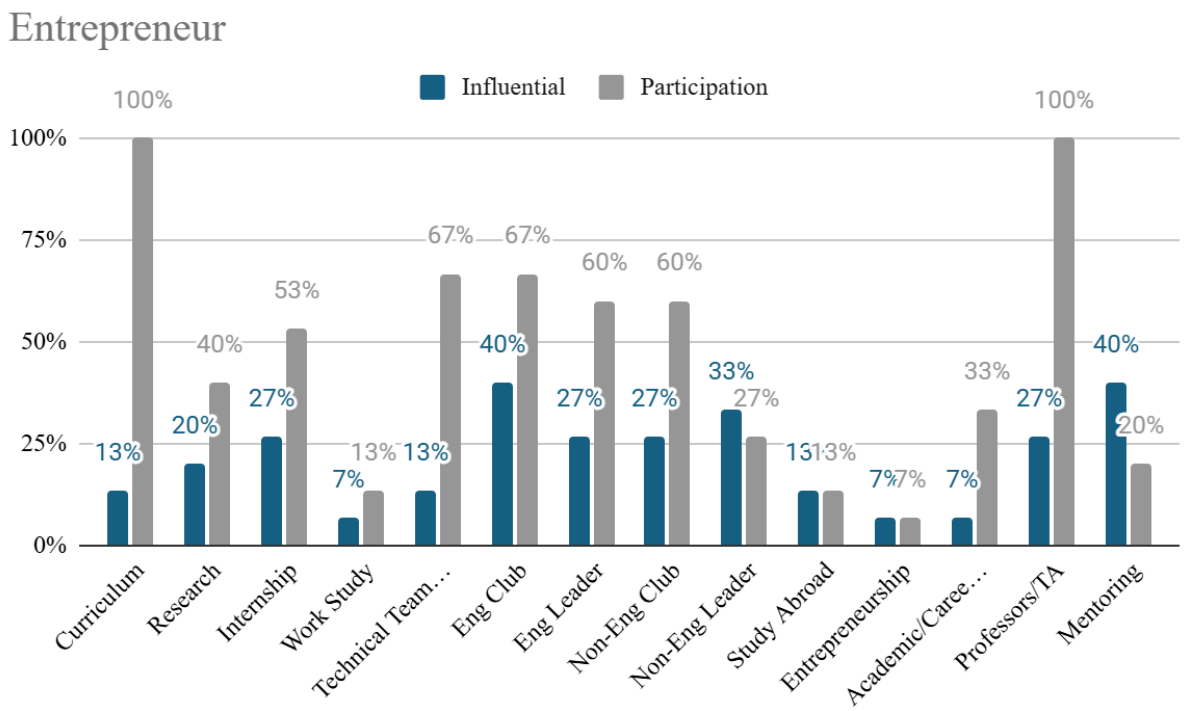

Figure 6. Influential Activities and Participation Rates for Entrepreneurial Career Paths

The quote below from an engineering graduate highlights the influence of an overseas experience on their Entrepreneurial career path.

> "I was hired through like a UN program that was hiring from the diaspora with specialized skills…My old boss when I was working [on the UN program], he was thinking about starting something."

The activities most commonly cited by those in Entrepreneurial career paths as influential were Mentoring and Engineering Clubs (40%). Technical team projects (13%) and Curriculum (13%) were not commonly cited as being influential by those in Entrepreneurial careers.

Invisible Engineer Career Path

Those who took Invisible Engineer career paths were the least likely to participate in Internships than any other career path (36% for Invisible Engineers vs. >50% for all other career paths) The activity most commonly cited by those in Invisible Engineer career paths as influential was Curriculum (57%). The Figure below shows the influential and participation responses for engineering graduates in Invisible Engineer career paths.

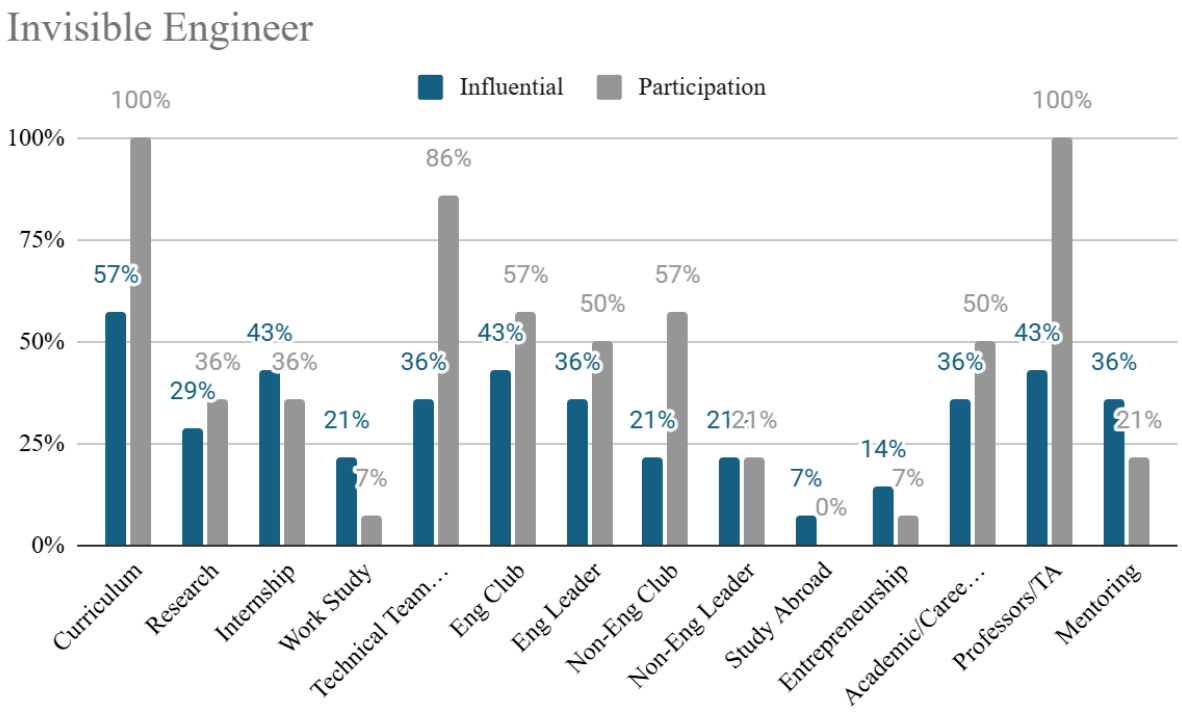

Figure 7. Influential Activities and Participation Rates for Invisible Engineer Career Paths

This quote from an engineering graduate illustrates how the curriculum developed problem solving skills that were relevant outside of engineering.

> "I will say it took me probably 10 years out of engineering to go back and be like, Oh, actually, my problem solving skills, like, people throw me the most complex problems whether it's like inside my organization or for our clients, and my ability to like sift through that and find some, some reasonable course of action, I think is my engineering brain."

Technical Specialist Career Path

Those who took Technical Specialist career paths were most likely to participate in Internships (80%) than any other career paths. They were also very likely to participate in technical team projects (88%). These activities were also most commonly cited by those in Technical Specialist career paths to be influential (internships (63%), followed by technical team projects (53%)). The Figure below shows the influential and participation responses for engineering graduates in Technical Specialist career paths.

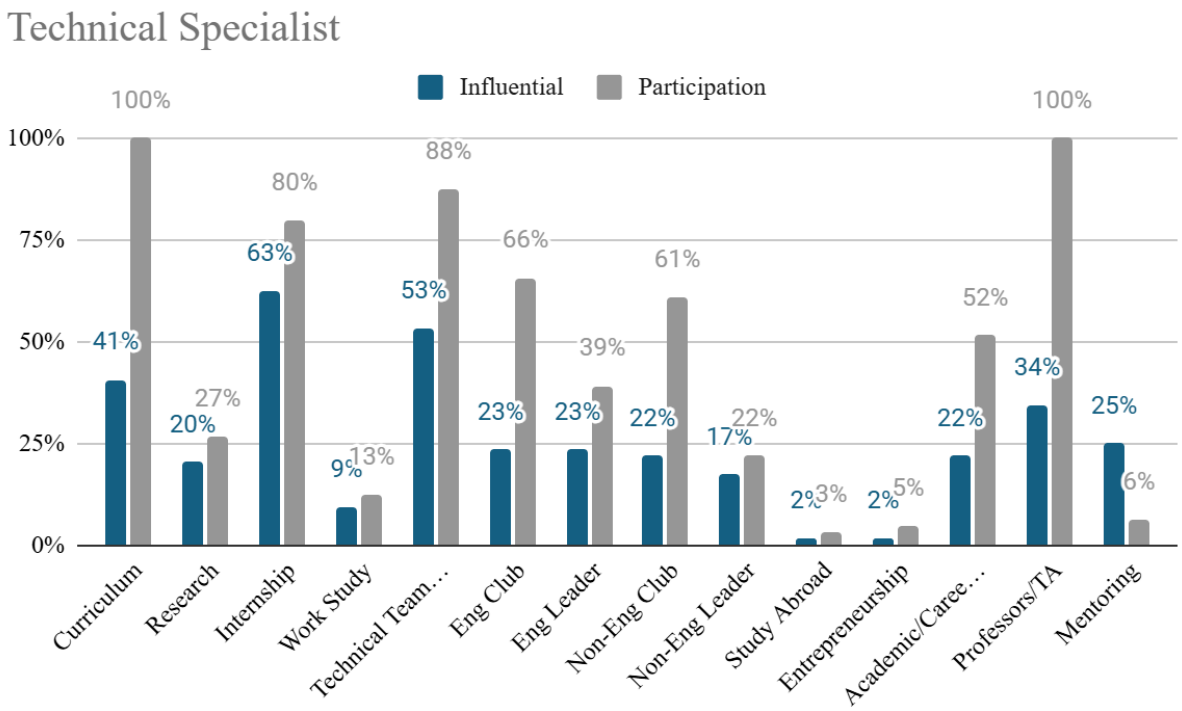

Figure 8. Influential Activities and Participation Rates for Technical Specialist Career Paths

The quotes below show the influence of internships and capstones for engineering graduates on the Technical Specialist career path.

> "I did have a summer internship in between the first and second year... I worked at a refinery and that gave me exposure into sort of where chemical engineering technology stops or maybe not stops, but how they meet, there are different scopes, right? And once I saw that, I knew I wanted to be on the engineering side."

> "I did learn a lot from my capstone because that played into my first job with instrumentation. The piece that I handled in the capstone was instrumentation. And my first job had to do with instrumentation as well."

"My degree project topic, of course, had to do with the industry that was prevalent..it's a pulp and paper sort of community. You have a paper mill, and by virtue of that, you have a company that I eventually worked at five years right from graduation."

Managerial Career Path

Those who took Managerial career paths were also likely to participate in Internships (76%). They were the most likely to participate in engineering clubs (72%) followed closely by the Boundary Spanners. Like Technical Specialists, the activity most commonly cited by those in Managerial career paths to be influential was Internships (64%). The Figure below shows the influential and participation responses for engineering graduates in Managerial career paths.

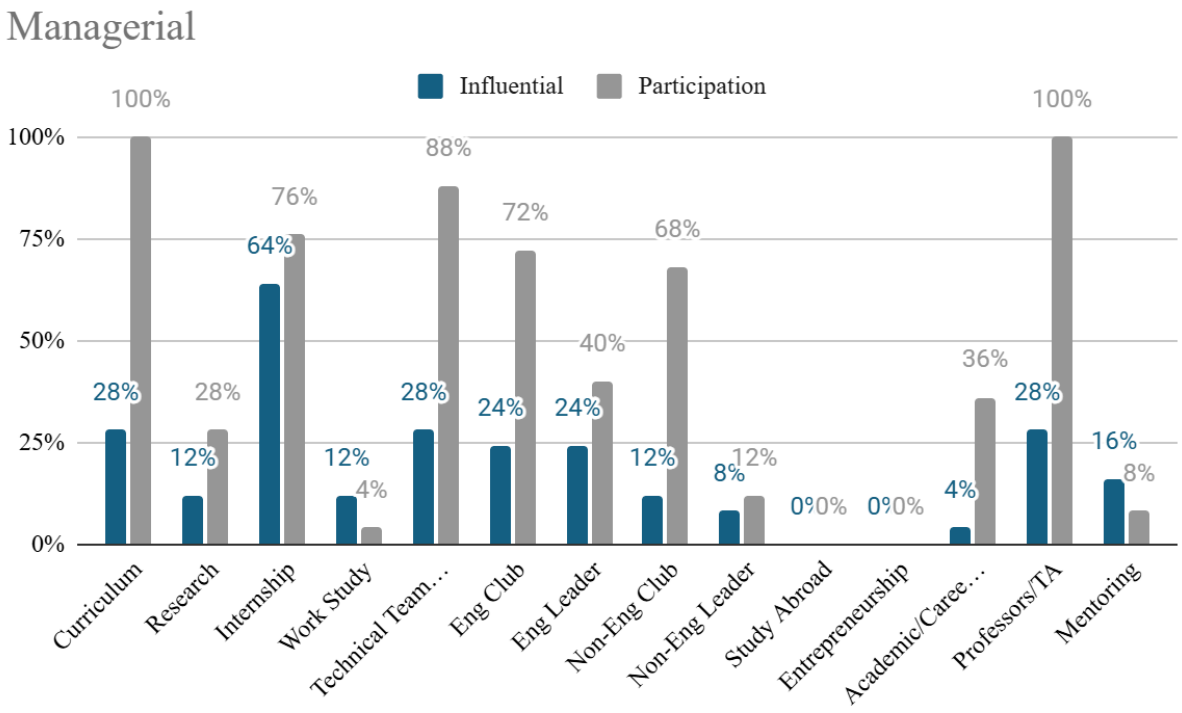

Figure 9. Influential Activities and Participation Rates for Managerial Career Paths

The quote below shows the influence of internships on the Managerial Career path.

"I was trying to understand where the trends were and then advising senior management about what those trends meant and trying to, sort of, predict what the data would also say in the coming months…. It was just a great 16-month experience in leadership, but also in project management and data analytics."

Synthesis

Overall it can be said that certain undergraduate activities could be considered more influential for some career paths. Table 2 below shows a heat map of the influence of activities by career paths.

Table 2. Heat Map of Undergraduate Activities to Career Paths

	Curriculum	Research	Internship	Work Study	Technical Team Project	Eng Club	Eng Leader	Non-Eng Club	Non-Eng Leader	Study Abroad	Entrepreneurship	Academic/Career Advising	Professors/TA	Mentoring	Co-curricular
Academic	**58%**	**58%**	50%	17%	25%	25%	33%	**0%**	0%	0%	8%	0%	**58%**	17%	8%
Boundary Spanner	33%	10%	52%	5%	**43%**	24%	33%	33%	19%	10%	5%	19%	38%	19%	38%
Entrepreneur	13%	20%	27%	7%	13%	**40%**	27%	27%	**33%**	**13%**	7%	7%	27%	**40%**	13%
Invisible Engineer	**57%**	29%	43%	21%	36%	43%	36%	21%	21%	7%	14%	36%	43%	36%	**50%**
Managerial	28%	12%	**64%**	12%	28%	24%	24%	12%	8%	0%	0%	4%	28%	16%	20%
Technical Specialist	41%	20%	63%	9%	**53%**	23%	23%	22%	17%	2%	2%	22%	34%	25%	20%

The only activity that was shown to have statistical significance is the influence of participation in undergraduate research activities on an academic career pathway. This aligns with other studies that show the influence of undergraduate research on pursuing graduate studies [14], [15], [16]. Further work can be done to review the demographics of students who participate in undergraduate research and the implications on the demographics of engineering graduates in academic career paths.

When considering other non-traditional career paths, additional work could be done to better understand the influence for entrepreneurial career paths. Participation in activities such as incubator programs and study abroad were too low to determine potential influence and more work could be done to explore further. More work can be done to explore in more granular detail the types of activities, for example rather than look at the influence of engineering vs non-engineering student clubs, perhaps specifically looking at the influence of engineering entrepreneurship student clubs.

The Boundary Spanner career path is also a non-traditional career path of interest. This career path had high influence from capstone and technical team projects. Capstone and technical team projects also showed high influence for other career pathways, which aligns with some other literature [17], [18], however additional research could be done to better understand exactly how the technical team projects influence specific career pathways. More work could also be done to be more granular on the aspects of the technical team project that is influencing career pathways, building on research looking at the student's role within team projects and the subsequent skill development [17], [19], [20], [21].

Across all career pathways, considering more granularity into the types of engineering activities could be considered, as well as exploring in more detail through qualitative analysis, the 'how' of the influence, could provide more insights into these findings. As an example, internships were frequently noted as influential across multiple career paths, but could the type of internship or industry/environment that the internship took place in, be more of an influence to the specific career pathway. This work provides a foundation to explore some of these areas in more detail in future research.

Conclusion

Those who took Academic career pathways were more likely to cite Curriculum, Research and Interactions with Professors as influential to their careers. Boundary Spanners were most likely to cite internships and technical team projects/capstone projects as influential. Entrepreneurs were most likely to cite engineering clubs and mentoring as influential. Invisible Engineers were most likely to cite the engineering curriculum as being influential. Technical Specialists and Managerial career paths both most commonly cited internships as being influential. The responses for influential activities were compared to activity participation. Certain career paths also had lower participation in specific activities than graduates who chose other careers.

This research can help engineering administrators and Faculty better support and advise students on determining which undergraduate activities to participate in that could influence their career pathways, and how those might influence them towards specific career paths, especially if students are considering paths beyond the traditional Technical and Managerial career paths. This work can also provide a foundation for exploring different demographics in various career paths and how that may correlate with the participation of certain demographics of engineering students participating in those activities. Lastly, this work also provides quantitative insights that can encourage more collaboration between industry and postsecondary through valuable student activities such as internships, technical projects, research and student clubs, as they have been cited to be influential for certain careers.

The main limitation of this work is that it only provides a high level broad analysis across undergraduate student activities. This work provides initial quantitative insight to various undergraduate activities across different possible engineering career paths, but future research can go into more detail and nuance for each specific undergraduate activity to tease out causation factors for the correlations noted in this study.

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