

Identifying the Skills and Student Activities that Influence Career Pathways for Black vs. non- Black Engineering Graduates

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Introduction

Background

Career pathways for engineering graduates have continued to shift over the past several decades and continue to evolve and engineering education evolves. With the increase of career pathways for engineering graduates there has been increasing research to better understand the influencing factors for students' choice in career pathways after graduation. Previous work compiled by has shown that participation in certain activities, such as engineering internship/co-op and study abroad experiences can influence the career path decisions of engineering graduates [1]. Extracurricular and co-curricular activities, such as club participation, undergraduate research and mentorship opportunities, can also be influential to career path decisions [2]. Though it has been noted that different demographics can choose different career pathways, most work has been done to look at gender and not at race[3], [4] . Research has begun to look more at race, though many studies group all underrepresented racial minorities (URM) into a group [5], with limited work focused specifically on Black engineering students.

Purpose and Research Questions

This paper aims to fill a gap in the literature, focusing specifically on Black engineering graduates and the skills and activities they identify as influential to their career paths as compared to their non-Black counterparts.

The purpose of this paper is to address the following research questions:

1. What are the skills and activities that Black and non-Black engineering graduates have cited as being the most important to their careers?
2. How do these skills and activities differ for Black vs non-Black engineering graduates?

Positionality Statement

Positionality can influence the research process in a number of ways [6], and for this reason I feel it is important for me to acknowledge my positionality as it relates to this research. I identify as a Black woman and was born and raised in the Caribbean before moving to Canada to study chemical engineering. I have since settled in Canada and have had a varied career pathway since graduating from my undergraduate degree. I completed my master's degree, worked in the oil and gas industry and then pivoted into the education and non-profit space. I personally identified specific activities during my undergraduate degree that influenced my career, including participation in students clubs like the National Society of Black Engineers

(NSBE) as well as participation in undergraduate research and technical team course projects. My experiences led me to pursue a PhD in engineering education looking at how the undergraduate student activities influence career pathways for underrepresented groups in engineering. This positionality influences this research by providing me the lived perspective of a Black engineering student and engineering graduate and has shaped how I have identified the activities and skills in this research.[7]

Design and Method

Conceptual Framework

The conceptual framework for this research and paper is based in Social Cognitive Career Theory (SCCT) [8]. SCCT proposes that learning experiences are influenced by both person inputs, such as predispositions and demographic factors, as well as by background and context. These learning experiences can then influence self-efficacy, which is aligned to an individual's belief that they can perform a certain task, as well as outcome expectations, which is aligned to an individual's expectations of what might occur if they were to make a certain choice. Self-Efficacy and Outcome Expectations are both influenced by learning experiences, which then influences a person's interests, goals and actions.

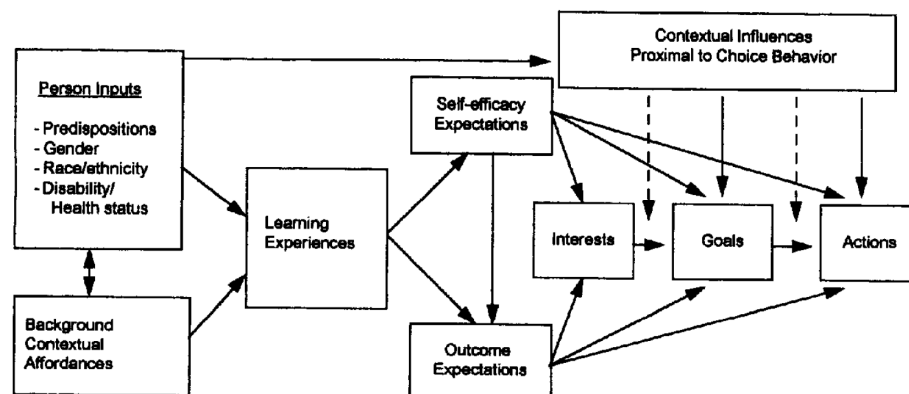


Figure 1. Model of social cognitive influences on career choice behavior. Note that dotted paths indicate moderator effects on interest-goal and goal-action relations. From "Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance" [Monograph], by R. W. Lent, S. D. Brown, and G. Hackett, 1994, *Journal of Vocational Behavior*, 45, p. 93. Copyright 1994 by R. W. Lent, S. D. Brown, and G. Hackett. Reprinted with permission.

Figure 1- A diagram of Social Cognitive Career Theory (Lent, 1994).

Learning experiences have been identified within the context of the undergraduate student experience, and have been categorized into various 'student activities' including curricular, co-curricular and extracurricular activities.[1], [9]

The Person Inputs for this study are focused only on race, and survey respondents were separated by those who identified as Black vs. those who did not identify as Black, i.e. 'non-Black'.

Methodology

A survey was developed leveraging previous survey instruments on engineering career paths, including the Pathways of Engineering Alumni Research Survey (PEARS)[10] and the Troost ILead Career Path Survey [11]. The survey included demographic questions as well as questions on the activities and skills that have been most influential in their career pathways. This survey was deployed between March 2023 to May 2023 to engineering graduates from various engineering programs across Canada, who had graduated at least 5 years prior. The survey was disseminated through the University of Toronto Engineering Alumni office, the Canadian Engineering Education Association newsletter, Black Engineers Canada newsletter and through social media posts on LinkedIn. Black engineering graduates were deliberately oversampled in the survey deployment.

The survey design was broken down into 4 sections:

1. Undergraduate Information - this section asked the respondent information about their undergraduate education, which institution they attended, when they graduated and which engineering discipline they studied.
2. Undergraduate Influence on Career Path - this section asked respondents about the activities they participated in during their undergraduate degree, which skills they developed and which skills and activities were most influential to their careers
3. Career Path - this section asked respondents about their career path post graduation
4. Demographics - this section asked respondents to identify their gender, race, ethnicity and other demographics

This paper is primarily focused on analyzing section 2 of the survey while leveraging data from section 4 of the survey to analyze based on race (Black vs. non-Black).

Results and Analysis

The total number of respondents to the survey was 289 respondents. 115 (40%) self-identified as Black, while 174 (60%) did not identify as Black and were classified as 'non-Black'. Of the 174 who did not identify as Black, 105 respondents identified as White/Caucasian. The remaining 69 identified as Indigenous (1), East Asian (17), Latin American (3), Middle Eastern (8), South Asian (14), Southeast Asian (3), another racial identity not listed (2), or chose not to disclose their racial identity (8), or did not respond (14).

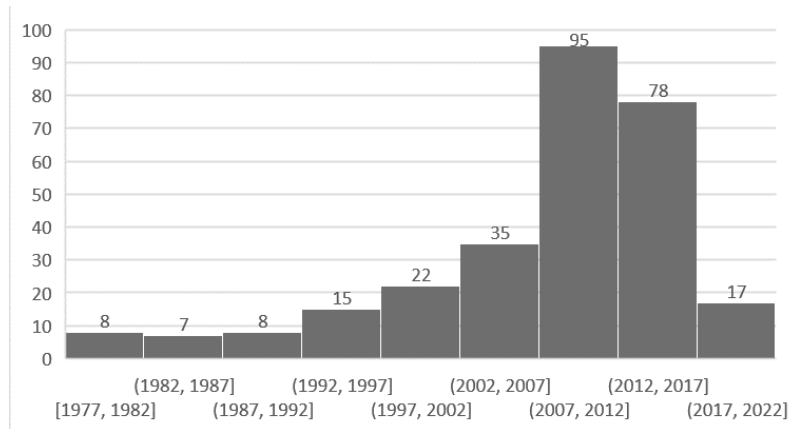


Figure 2: Breakdown of Survey Respondents by Graduation Year.

Respondents graduated from an engineering undergraduate degree between 1977 and 2022, with the highest proportion of respondents (95, 33%) graduating between 2007 and 2012. 152 respondents identified themselves as Men, and 78 of those Men identified as Black. 120 respondents identified themselves as Women, and 37 of those women identified as Black. 17 respondents identified as another gender or chose not to respond, none of which identified as Black.

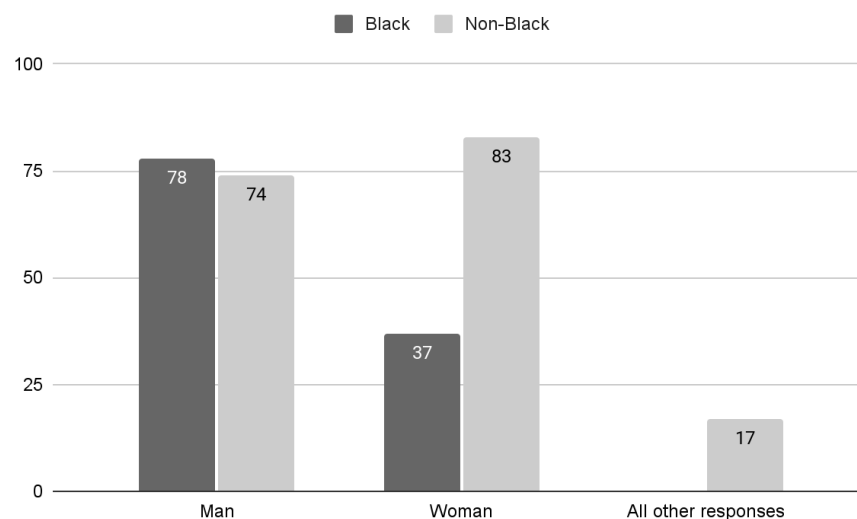


Figure 3: Breakdown of Survey Respondents by Gender.

Activity Participation

In the survey, respondents were asked to select which activities they participated in during their engineering undergraduate degrees. See Figure 7 in the appendix for an example of the options. Table 1 below includes the response options, and how they have been coded for analysis.

Table 1: Options for Activity Participation and Corresponding Code for Analysis.

<u>Response</u>	<u>Code</u>
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

Technical team projects were the most common activity that engineering graduates participated in during their undergraduate degrees, with 83% (95) Black respondents participating and 84% (147) of Non-Black respondents participating. The least common activities were entrepreneurial activities and study abroad, which were low for both Black (4% and 3%, respectively) and non-Black (3% and 6%, respectively) respondents. Chi-squared analysis was conducted to test if the activity participation during undergrad was statistically significant between Black and non-Black engineering graduates. This showed that there is a statistically significant difference in the activities that Black students choose to participate in vs. those who do not identify as Black,

$\chi^2(11, N=1260) = 24.23, p < .05$. A Chi-squared analysis was also done on each individual activity and some were deemed statistically significant at $p < .5$ and others were not statistically significant. The activities with a statistically significant difference were academic advising, participation and leadership in engineering clubs, leadership in non-engineering clubs, and work-study.

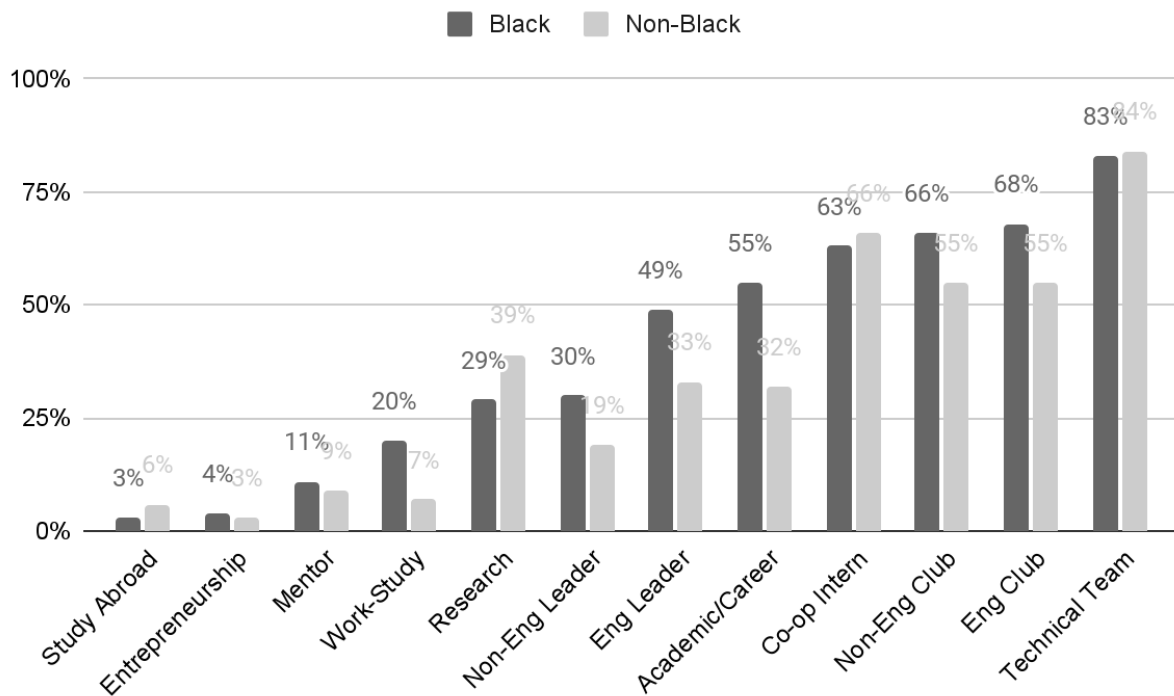


Figure 4: Undergraduate Activity Participation for Black vs. Non-Black Engineering Graduates.

Important Skills

Engineering graduates were asked which skills/competencies have been most important for their careers. A list of skills was provided including:

- Technical skills (Engineering knowledge base, Problem solving, Analytic thinking, Investigation, Design, Use of engineering tools)
- Interpersonal (Teamwork, Conflict resolution, Supporting/motivating others)
- Communication (visual, verbal, written)
- Leadership (Project management, Deciding what problem to solve, Negotiation, Driving change)
- Business / Financial Acumen
- Societal impact (Environmental impact, Equity, Ethics)
- Lifelong learning
- Innovation (agility, creativity)

- Self-Confidence (Self-Esteem, Sense of Belonging)
- Independence (Self-autonomy, Self-sufficiency)

For each of these competency areas, respondents were asked to rate them on a likert scale of “Not Important at All” to “Extremely Important”. See Figure 8 in the appendix for an example of the question as presented in the survey.

Based on the responses, Communication and Interpersonal skills were most frequently deemed as ‘extremely important’ or ‘very important’ by both Black and non-Black engineering graduates. 97% of Black respondents and 89% of non-Black respondents deemed Communication skills as either ‘extremely important’ or ‘very important’. 94% of Black respondents and 86% of non-Black respondents deemed Interpersonal skills as either ‘extremely important’ or ‘very important’. Self-Confidence, Independence and Leadership were also frequently deemed important by both Black and non-Black engineering graduates, all of which had 75% of respondents or more citing them as important skills to their careers.

Societal Impact and Business/Financial Acumen were the least frequently cited as being ‘extremely important’ or ‘very important’ skills. Only 36% of Black respondents and 34% of non-Black respondents deemed Societal Impact skills as either ‘extremely important’ or ‘very important’. 50% of Black respondents and 38% of non-Black respondents deemed Business/Financial skills as either ‘extremely important’ or ‘very important’.

Chi-squared analysis was conducted to test if the perception of most important skills for careers was statistically significant between Black and non-Black engineering graduates. This showed that there no statistically significant difference in the perception of important skills for those who identify as Black vs. those who do not identify as Black, $\chi^2 (9, N=1990) = 1.853, p>.05$. However, when considering the chi-square value for each individual skill, there is statistical significance in the difference for Business/Financial Acumen as well as for Self-Confidence.

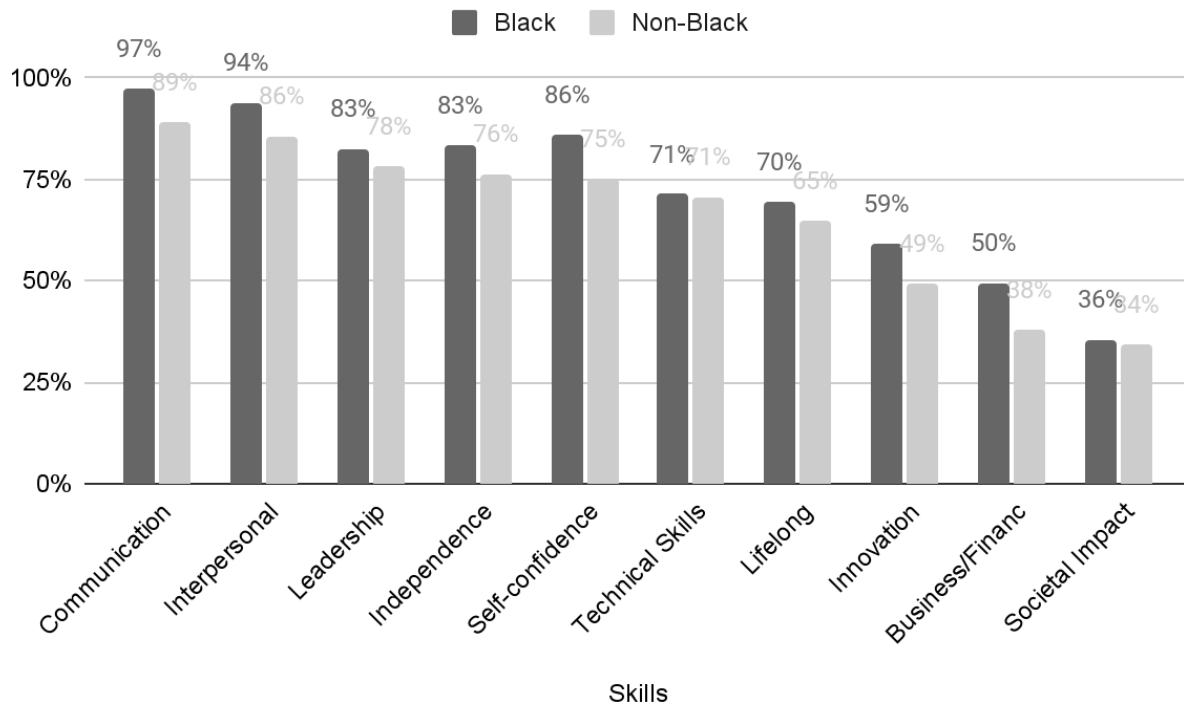


Figure 5: Important Skills for Black vs. Non-Black Engineering Graduates.

Influential Activities

Engineering graduates were also asked which activities were most influential to their career pathways. This question was similar to the question on activity participation, but also included additional ‘mandatory’ activities, including “Undergraduate Course Curriculum” and “Interactions with Professors/TAs”. These were also ranked on a likert scale of “Not Influential at All” to “Extremely Influential”. See Figure 9 in the appendix for an example of the question as presented in the survey. The total number of times an activity was selected as ‘Very Influential’ or ‘Extremely Influential’ was divided by the total number of respondents to determine the percentage of respondents that cited the activity as influential.

Co-ops/internships were the activity that engineering graduates selected most frequently as being influential to their careers, with 52% (60) Black respondents and 51% (88) of Non-Black respondents participating.

The second most frequently selected activity deviated for Black and non-Black respondents. Black respondents selected Technical Team Projects as the second most influential activity, with

42% (48) of Black respondents selecting this activity, vs. 30% (52) of non-Black respondents. Technical team projects was the fourth ranked for non-Black respondents.

Multiple activities showed a difference in frequency between Black and non-Black respondents. Participation in engineering clubs showed 31% (36) of Black respondents deeming it influential vs. on 17% (29) of non-Black respondents. Similarly for non-engineering student clubs, 29% (33) of Black respondents deemed influential vs. 16% (28) non-Black respondents. Academic and Career Advising was deemed influential more frequently by Black respondents than non-Black, with 25% (29) of Black respondents vs. only 7% (12) of non-Black respondents deeming it influential. Alternatively, non-Black respondents more frequently deemed undergraduate research as influential as compared to Black respondents, with only 15% (17) of Black respondents saying research was influential vs. 27% (47) of non-Black respondents.

Chi-squared analysis was conducted to test if the perception of influential undergraduate activities was statistically significant between Black and non-Black engineering graduates. This showed that there is a statistically significant difference in the activities that Black graduates deem as influential vs. those who do not identify as Black, $\chi^2(14, N=982) = 36.80, p < .05$. A Chi-squared analysis was also done on each individual activity and some were deemed statistically significant at $p < .5$ and others were not statistically significant. The activities with a statistically significant difference were co-curricular activities, mentorship, academic advising, participation and leadership in both engineering and non-engineering clubs, technical team projects, and research.

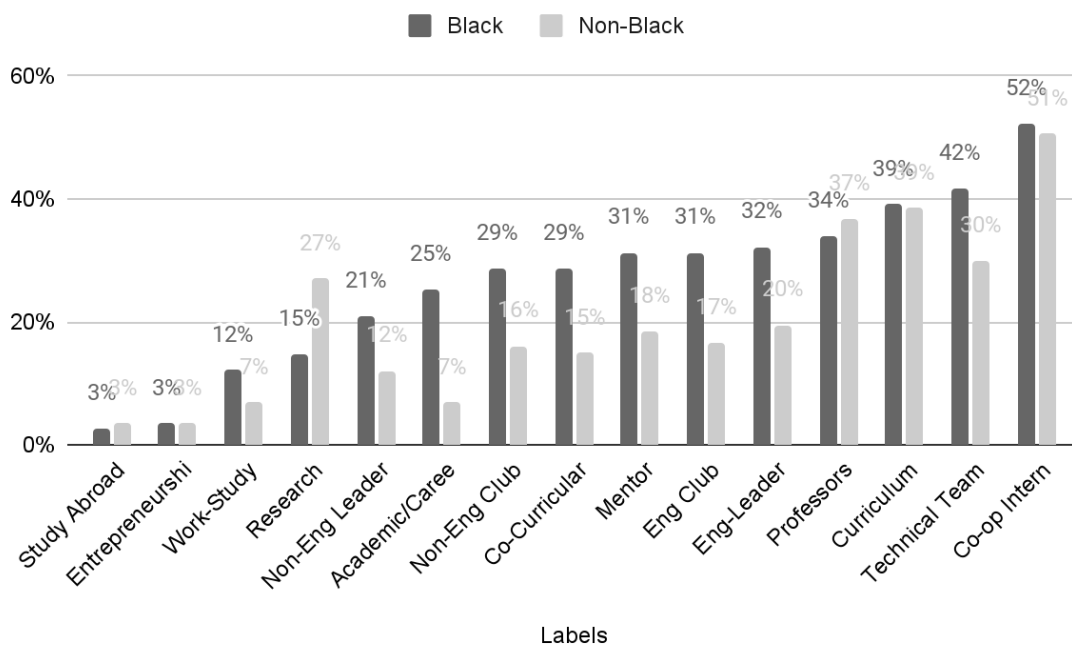


Figure 6: Most Influential Undergraduate Activities for Black vs. Non-Black Engineering Graduates.

Discussion

The research questions aimed to look at two aspects (1) What are the skills and activities that Black and non-Black engineering graduates have cited as being the most important to their careers? And (2) How do these skills and activities differ for Black vs non-Black engineering graduates? Reviewing the results, the discussion can focus on the influential skills and how they differ for Black vs. non-Black; as well as the activities and how they differ for Black vs. non-Black.

Skills

The rankings of most important skills for Black and non-Black engineering graduate are shown in Table 2 below:

Table 2: Rankings of Top Skills for Black and Non-Black Engineering Graduates.

	Black	Non-Black
Top 5	1. Communication 2. Interpersonal Skills 3. Self-Confidence 4. Independence 5. Leadership	1. Communication 2. Interpersonal skills 3. Leadership 4. Independence 5. Self-Confidence
Bottom 5	6. Technical Skills 7. Lifelong Learning 8. Innovation 9. Business/Financial Acumen 10. Societal Impact	6. Technical Skills 7. Lifelong Learning 8. Innovation 9. Business/Financial Acumen 10. Societal Impact

For both Black and non-Black engineering graduates, the top 5 skills were the same, with Leadership and Self-confidence in different orders. This aligns with multiple studies that show that ‘soft skills’ or ‘human skills’ are more important to careers. [2], [5], [12].

Statistical analysis showed a significance in the number of Black graduates rating Self-confidence as influential vs. non-Black. This does align with literature that shows the impact of confidence on Black students [13].

Business/Financial Acumen also showed statistically significant difference even though it was still ranked in the bottom for both Black and non-Black graduates. This could indicated that more Black graduates are pursuing careers with a business or finance focus, like project management.

Societal Impact was lowest ranked for both Black and non-Black engineering graduates as being important to their careers. This may reflect some of the traditional engineering mindsets that show a dichotomy between engineering work and social impact work [14].

Overall, Black engineering graduates ranked all of the skills as influential more frequently than non-Black participants. It is difficult to state why this is the case, but perhaps could be due to the larger proportion of Black students participating in academic advising, which can shape self-efficacy in certain skills and affect student persistence and ultimately careers, especially for Black students [13], [15]. This could be explored more deeply in further research.

Activities

When reviewing the activities, this is where we saw more of a difference between Black and non-Black engineering graduates. The analysis showed that there is a statistically significant difference between the types of activities that Black vs non-Black students participate in, as well as a statistical significance between the activities that Black vs. non-Black graduates find to be influential.

The rankings of influential activities for Black and non-Black engineering graduates are shown below.

Table 3.

	Black	Non-Black
Top 5 Activities	1. Co-op Intern 2. Technical Team Projects 3. Curriculum 4. Professors 5. Eng-Leader	1. Co-op Intern 2. Curriculum 3. Professors 4. Technical Team Projects 5. Research
	6. Mentor 7. Eng Club 8. Co-Curricular 9. Non-Eng Club 10. Academic/Career Advising	6. Eng-Leader 7. Mentor 8. Eng Club 9. Non-Eng Club 10. Co-Curricular
Bottom 5 Activities	11. Non-Eng Leader 12. Research 13. Work-Study 14. Entrepreneurship 15. Study Abroad	11. Non-Eng Leader 12. Academic/Career Advising 13. Work-Study 14. Entrepreneurship 15. Study Abroad

While the top 4 activities are the same for both groups, Black graduates cite leadership in an engineering club as being top 5 of influential activities to their careers and Non-Black graduates did not have leadership in an engineering club in the top 5. In general, Black graduates more frequently rated involvement in student clubs as influential than non-Black students. As noted in the results section, Black students also participated as leaders in student clubs at a statistically significant higher frequency than non-Black students. This could be due to the influence of the National Society of Black Engineers (NSBE), as many of the Black participants were sourced through networks associated with NSBE, and previous research has shown that NSBE can be influential to self-efficacy in skills like leadership, and can influence the experience and future careers of Black engineering students [7], [16], [17], [18].

Alternatively, non-Black students included undergraduate research as being in the top 5, compared to Black students who actually had this activity in the bottom 5. Research does show that undergraduate research activities can be influential to skill development [19], however when considering the participation rate for Black students (only 39% said they participated in an undergraduate research activity), this could be a reason why the importance ranking is lower. Though it was not statistically significant, there was a lower percentage of Black students participating in research activities. With SCCT as a framework, it can be assumed that Black engineering students are not gaining the self-efficacy and interest in research, or perhaps there are other contextual factors such as family influence, and thus Black students are not pursuing research related careers. This aligns to literature that shows Black engineering graduates being less likely to follow academic career paths [20], and this could also be a reason why research was less influential to their careers.

Technical team projects were included in the top 5 for both Black and non-Black engineering graduates, and though participation in these projects was not statistically significant, the percentage of Black graduates rating technical team projects as influential was significantly higher than non-Black graduates. This is showing that even though both Black and non-Black students gain value from these technical team projects, Black students value them more highly. Further research can explore why this is the case and how this may influence career pathways.

Another noted difference between Black and non-Black engineering graduates was the influence of Academic/Career advising. 25% of Black graduates noted it to be influential vs. only 7% of non-Black engineering graduates. It should be noted that there was a statistical significance of non-Black students being less likely to participate in Academic/Career advising, with only 32% on non-Black graduates reporting to have participated, vs. 55% of Black graduates.

It should also be noted that for both Black and non-Black engineering graduates, Work-Study, Entrepreneurship activities, and Study Abroad were the bottom 3 activities. These were also the activities that had some of the lowest participation rates, so these activities may actually be quite

influential. For example, 3% of Black graduates reported to participate in study abroad and 3% also cited it as influential. This means 3/3 or 100% of those that participated found it to be influential. For entrepreneurship 4% of Black graduates reported to participate in study abroad and 3% also cited it as influential, so $\frac{3}{4}$ or 75% of those who participated found it to be influential. These numbers are fairly similar for the non-Black graduates. With the low participation in entrepreneurship programs for both Black and non-Black graduates, with SCCT as a framework, it can be assumed that few engineering graduates are developing the self-efficacy and interest in entrepreneurship, and thus few are considering entrepreneurial career pathways.

The results for mentoring were interesting. Though mentoring was ranked in the middle for influential activities, it was ranked quite low on participation. Only 11% of Black engineering graduates and 9% of non-Black graduates reported participating in some sort of formal mentoring program. Though 31% of Black engineering graduates and 18% of non-Black said that mentoring was influential, which was a statistically significant difference. This could potentially show that engineering graduates, especially Black engineering graduates, are considering non-formal mentoring opportunities as being influential, even when they did not participate in a formal mentoring program. This aligns with research that shows the value of mentoring, both formal and informal [13], [21], [22], [23] and could influence the careers of engineering graduates to pursue the careers similar to that of their mentors, as mentorship can lead to increased understanding of outcome expectations which according to SCCT can influence careers, especially for Black students [13].

Lastly, it should be noted that in general, non-Black graduates seemed to rank the listed activities less frequently as important than the Black graduates, and also seemed to participate in less of the listed activities. This could mean that non-Black students are more likely to participate in other activities during their undergraduate, for example sports or arts [24], or are not participating in activities because they don't deem them to be as important as Black students do. This could be something to investigate further in future research.

Recommendations

Recommendations for Students

Based on the analysis and discussion, some key takeaways and recommendations for students are:

- Black students should consider joining various student clubs, both engineering and non-engineering related
- Both Black and non-Black students, but Black students in particular, should ensure they have a mentor to support them through the student experience and into careers because this can be influential

- Engage in in-class technical team projects
- Take advantage any supports from the institutions to gain access to co-op and internship opportunities
- Engage with your professors and TAs because they can be influential to your careers

Recommendations for Administrators

Based on the analysis and discussion, some recommendations that educational administrators in engineering undergraduate programs should consider are:

- More access to study abroad programs, entrepreneurship and formal mentoring programs
- Academic and Career advising is important to Black students
- Increase access to undergraduate research for Black students
- Both Black and non-Black students cite internships and technical team projects as being influential, there needs to be supports in place to ensure all students have access to these
- Professors and TAs should have the supports they need to effectively engage and support undergraduate students, because their interactions can be influential to the students' careers
- Curriculum can be influential to students, ensuring that it is designed to teach the skills that are most important for students' future careers. Those skills include Communication, Interpersonal Skills, Self-Confidence, Independence, Leadership, followed by Technical skills.

Limitations

A few limitations should be noted for this work. This data was gathered from engineering graduates that completed their degree at least 5+ years ago, with most completing their degrees 10-15 years ago. Engineering undergraduate activities may have evolved and changed over time and some of these activities listed may not be as relevant, or may be more relevant.

Another limitation when analyzing the activities that were influential, this did not take into account the participation in an activity. For example, 3% of Black respondents participated in study abroad, and 3% of Black respondents said that study abroad was influential. It could be assumed that 100% of Black graduates who participated in study abroad found it influential, however with the sample so small, it is difficult to draw that conclusion. This could be explored more deeply in further analysis and future research.

It should also be noted that this work was situated in Canada. Skills and activities may be different for different countries or geographical regions. Lastly, it should be noted that the survey respondents primarily came from the author's own network through dissemination on LinkedIn, this may have skewed the results, as there may be more respondents that may have participated in the similar activities to the author.

Conclusion and Contributions

This study aimed to answer two research questions (1) What are the skills and activities that Black and non-Black engineering graduates have cited as being the most important to their careers? And (2) How do these skills and activities differ for Black vs non-Black engineering graduates? The analysis showed that soft skills such as Communication and Interpersonal skills were most important for Black and non-Black engineering graduates, and that activities like co-op/internships and technical team projects were influential for Black and non-Black engineering graduates. The study also highlighted differences in activities for Black and non-Black engineering graduates, for example Black graduates are more likely to find student clubs and academic advising as influential than their non-Black counterparts. Lastly, the study posed recommendations to both students and academic administrators based on the findings.

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Appendix: Additional Figures

- 5) When you were an undergraduate engineering student, did you participate in any of the following (select all that apply)?
- ☐ Conduct research with a faculty member
 - ☐ Work in an engineering environment as an intern/co-op
 - ☐ Participate in a work-study program (non-engineering role or non-research)
 - ☐ Work on technical team-based projects as part of a course
 - ☐ Participate in activities hosted by engineering-related student clubs, groups, or community service (e.g., Engineers Without Borders)
 - ☐ Serve as a leader in an engineering student organization
 - ☐ Participate in activities by student clubs, groups, or community service outside of engineering
 - ☐ Serve as a leader in a non-engineering student organization
 - ☐ Participate in a study abroad program
 - ☐ Participate in an incubator or entrepreneurship program
 - ☐ Utilize academic/career advising services
 - ☐ Participate in a formal mentoring program

Figure 7: Example of survey question and response options for undergraduate activity participation.

Which of the following knowledge and competencies have been most important for your career so far?					
	Not important at all	Somewhat important	Moderately important	Very important	Extremely important
22) Technical skills (Engineering knowledge base, Problem solving, Analytic thinking, Investigation, Design, Use of engineering tools)	☐	☐	☐	☐	☐
23) Interpersonal (Teamwork, Conflict resolution, Supporting/motivating others)	☐	☐	☐	☐	☐
24) Communication (visual, verbal, written)	☐	☐	☐	☐	☐
25) Leadership (Project management, Deciding what problem to solve, Negotiation, Driving change)	☐	☐	☐	☐	☐

Figure 8: Example of survey question for important skills.

How influential has the following experiences from your undergraduate degree been on your career choices?						
	Not influential at all	Somewhat influential	Moderately influential	Very influential	Extremely influential	I did not participate in this experience when in my undergrad
6) Undergraduate course curriculum (i.e. specific courses that you took during your undergraduate)	☐	☐	☐	☐	☐	☐
7) Conducting research with a faculty member	☐	☐	☐	☐	☐	☐
8) Working in an engineering environment as an intern/co-op	☐	☐	☐	☐	☐	☐
9) Participating in a work-study program (non-engineering role or non-research)	☐	☐	☐	☐	☐	☐
10) Working on technical team-based projects as part of a course	☐	☐	☐	☐	☐	☐
11) Participating in activities hosted by engineering-related student clubs, groups, or community service (e.g., Engineers Without Borders)	☐	☐	☐	☐	☐	☐

Figure 9: Example of survey question for most influential undergraduate activities.