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Gatekeepers of Engineering Workforce Diversity? The Academic and Employment Returns to Student Participation in Voluntary Cooperative Education Programs

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Abstract

This study examines the effect of participation in cooperative education (co-op) programs on engineering undergraduate students' academic and employment outcomes, with particular attention to diversity in engineering. Co-ops are partnerships between an academic institution and an employer designed to engage students in early practical work experience through rotations of full-time employment and full-time traditional classroom study. Previous studies highlight the positive academic and employment returns to participating in co-ops. However, among voluntary co-ops, it is unclear to what extent these potential benefits can be attributed to the causal effect of engagement in co-ops versus the selection of higher-performing students. This study addresses this selection issue by using propensity score matching. Data come from 12 cohorts of engineering undergraduate students from a large, research-intensive institution in the Midwest. Results indicate that co-op participants are more likely to graduate in an engineering major and to have higher overall grade point averages compared to their non-co-op peers. On average, co-op participants are also more likely to obtain engineering jobs and to earn higher starting salaries post-graduation than their non-co-op peers. Although Hispanic/Latino students are less likely to participate in co-ops, underrepresented racially minoritized students who complete co-ops are more likely to graduate in engineering and to earn higher starting salaries post-graduation than those who do not participate. Research findings provide support for promoting co-ops as a potential strategy to help improve student academic and employment outcomes with implications for potentially diversifying the engineering workforce downstream.

Keywords Cooperative education programs · Diversity · Persistence · Employment outcomes · Propensity score matching · Engineering

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Introduction

Achieving greater diversity in the engineering workforce improves not only equity, but also the quality of and creativity in engineering innovations (National Academy of Engineering 2002, 2005; Wulf 2001). Although the number of engineering degrees awarded to underrepresented racially minoritized (URM) students increased from 2011 to 2016, Black and Hispanic students are still underrepresented in engineering (Anderson et al. 2018; National Center for Science and Engineering Statistics [NCSES] 2019). In 2016, Black students comprised merely 4%, and Hispanic students only 11%, of engineering bachelor's degrees earned (NCSES 2019). In terms of the six-year graduation rates of first-time, full-time engineering students, African American/Black and Hispanic/Latino students complete engineering degrees at relatively lower rates than their counterparts (American Society for Engineering Education [ASEE] 2017). Passel and Cohn (2017) suggested that the engineering field will need to become more racially and ethnically diverse to maintain workforce numbers and to drive future innovation and progress. Even though policies have been enacted to increase the participation and persistence of underrepresented student populations in engineering, progress in diversification has been slow (Lichtenstein et al. 2016). Issues of inclusion and equity in engineering education need to be addressed to improve the lived experiences of minoritized engineering students and graduates in the engineering workforce (e.g., Long and Mejia 2016; Rodriguez and Morrison 2019). Developing educational changes and high-impact practices that increase student affiliation with engineering have the potential to improve the persistence and employment outcomes of diverse students—and cooperative education programs (co-ops) offer one such promising avenue for intervention.

Co-ops are partnerships between an academic institution and an employer designed to engage students in practical work experience through rotations of full-time employment and full-time traditional classroom study. Some engineering programs require co-ops as mandatory experiences, while other engineering programs provide co-ops as voluntary opportunities. It is widely accepted that co-ops provide students with discipline-relevant professional experience and early entry into the workforce. Previous studies have highlighted the positive academic and employment returns to participating in co-ops (e.g., Korte et al. 2008; Kovalchuck et al. 2017; Parsons et al. 2005; Raelin et al. 2014). However, among voluntary co-ops, it is unclear to what extent these potential benefits can be attributed to the causal effect of engagement in co-ops versus the selection of higher-performing students through a formal application and interview process, including minimum grade point average (GPA) requirements. Our study addresses this selection issue by using propensity score matching analysis, which compares the outcomes of matched pairs of students with similar observable characteristics. This approach has been applied in a number of studies to estimate the impact of educational interventions on student outcomes (e.g., Franke and Bicknell 2019; Melguizo 2010; Turk 2019). By incorporating pre-co-op information and using propensity score matching to balance factors associated with co-op participation, we construct a meaningful comparison group for co-op participants, and thus, our analyses address the possibility of conflation between benefits of co-ops and the caliber of students selected into these programs.

We examine whether co-op participation influences student academic and early employment outcomes by focusing on (1) persistence in an engineering major, (2) final GPA, (3) attainment of a post-graduation job in engineering, and (4) starting salary. Moreover, we identify the characteristics of students who are more likely to participate in co-ops and investigate whether there are differential returns to participation by student gender and race/ethnicity. Thus, this study addresses the following research questions:

1. Which demographic characteristics and academic achievement factors are associated with co-op participation?
2. Are co-op students more likely than non-co-op students to graduate in any major, persist in an engineering major, and to earn higher final GPAs? Are there differences in these outcomes by gender and race/ethnicity?
3. Are co-op students more likely than non-co-op students to obtain post-graduation jobs in engineering and to earn higher starting salaries, and are there differences by gender and race/ethnicity?

While our findings have potential to directly impact the development of strategies and programs surrounding professional development of engineering undergraduate students, there are also broader implications related to diversifying the engineering workforce. Because participation in voluntary co-ops serves as an important bridge between college engineering education and the engineering workforce, it may also serve as a "gatekeeper" to these opportunities to gain early engineering work experience and connections to relevant professional networks. As such, equitable access to co-ops may contribute to broadening the participation of URM students in the engineering workforce. Co-ops may also contribute to reducing differences in academic and employment outcomes across race/ethnicity and gender (Ramirez et al. 2015). Overall, our research findings have implications toward enhancing student educational achievement and employment attainment, as well as in increasing the overall diversity of the engineering and broader science and technology workforce. Because co-ops are available across many academic fields, our findings also have the potential to be applicable to other fields offering voluntary co-ops and other similar work experience opportunities with eligibility requirements.

Background and Literature Review

Co-ops in Engineering

Co-ops in engineering are designed to provide students with professional experience relevant to their academic discipline through alternating cycles of paid full-time employment and traditional full-time classroom education. Herman Schneider, an engineering professor at Lehigh University, developed the concept in 1901 (Grayson 1993; Wankat et al. 2002). He surveyed the engineering graduates from Lehigh University and noted that those individuals who had practical experience prior to graduation were more successful in their careers than their peers without pre-graduation practical experience. And thus, he started the first co-op program at the University of Cincinnati in 1906. Other academic institutions created similar programs, and by 1962 there were 150 co-op programs in the United States (Grayson 1993; Wankat et al. 2002). As of 1996, the Directory of College Cooperative Education (DCCE) reported that the number of co-op programs had grown to 460 across a wide variety of institutions and academic majors. The DCCE estimates that approximately 50,000 employers participate in co-op programs, including 85% of the top 100 companies on the Fortune 500 List.

A common path into a voluntary engineering co-op program is for an interested student to apply for a co-op position during their sophomore year after having selected a major and completed the core/introductory engineering courses. In addition to course requirements, many universities require a minimum GPA for co-op participation. The eligibility requirements are institution-specific and can vary by discipline and at the discretion of the co-op employer. Employers advertise co-op position openings through the university co-op office, which facilitates the matching process. Commonly, students send résumés to co-op employers from among a list of advertised positions. Program administrators pre-screen the students' résumés to ensure eligibility before connecting them to the prospective employers. This pre-screening, along with the specified eligibility requirements, inevitably functions as gatekeeping to early access to some of the top Fortune 500 companies and to select jobs and sustained relationships that co-op companies offer.

Student Participation in Co-ops

Students seek co-op opportunities to gain field-specific work experience, as well as to increase their future job prospects. Previous studies have found that co-op students perceived improved employability, work experience, and compensation/salary to be benefits of co-op participation (Anderson et al. 2012; Johnson and Main 2019; Ramirez et al. 2016; Strubel et al. 2015; Wanless 2013). For example, students interviewed about their co-op experiences indicated that their primary reason for pursuing these work experiences included increased employability (Wanless 2013). Other perceived advantages to co-op participation include gaining a competitive edge in the job market, job training, networking opportunities, and further career exploration (Ramirez et al. 2016). On the other hand, some students indicated in interviews that extended time to graduation, not wanting to miss on campus opportunities, and being off-sequence in courses from their entering cohort as reasons for not pursuing co-ops (Ramirez et al. 2016). In general, student lack of interest in co-ops is a common barrier to co-op participation (Johnson and Main 2019; Ramirez et al. 2016).

Some students interested in gaining engineering work experience also consider internships rather than co-ops. Internships are typically single-term work experiences completed during the summer term, and are often shorter in duration than co-ops because they do not tend to involve multiple rotations at the same company. Among students who choose internships instead of co-ops, students indicate that they want the engineering professional experience, but not the longer-term commitment associated with the multiple rotations of co-ops (Ramirez et al. 2016). Meanwhile, some students prefer co-ops to internships because they perceive co-ops to provide relatively more "in-depth" work experiences and a greater likelihood of resulting in a full-time post-graduation job offer compared to internships (Johnson and Main 2019). Although students' reasons for participating in co-ops can vary, studies have shown that students with higher academic achievement (based on GPAs) during the application process are more likely to participate in co-ops (e.g., Main et al. 2020).

Academic Returns to Participation in Co-ops

Many engineering students have reported having low exposure to engineering prior to college (Lichtenstein et al. 2007), which can lead to an uncertainty in their choice of major and lower persistence in engineering. Co-ops can help mediate this uncertainty by providing exposure to engineering-specific work experience and allowing students to explore their interests within the engineering field (e.g., NAE 2005; National Association of Colleges and Employers 2016). These experiences can motivate students to stay in engineering programs, enabling them to make connections between coursework and engineering practice (e.g., Raelin et al. 2014; Samuelson and Litzler 2013). Researchers have consistently linked co-op experiences to positive academic outcomes, including higher retention in engineering majors and higher GPAs (Blair et al. 2004; Main et al. 2020; Ramirez et al. 2015; Samuelson and Litzler 2013; Schuurman et al. 2008). For example, Main et al. (2020) found that co-op participation is positively associated with the likelihood of graduating in engineering, which is consistent with a study by Ramirez et al. (2015) analyzing the graduation probability of co-op students across six academic institutions. Samuelson and Litzler (2013) identified the key role of work experience in students' decisions to persist in engineering. In interviews with 27 female engineering students with co-op or internship experiences, participants indicated that the engineering-specific work experiences provided them with a greater understanding of the engineering field and post-graduation work opportunities, as well as networking opportunities and mentorship. Meanwhile, Raelin et al. (2014) analyzed 2461 survey responses from undergraduate engineering students across four universities and found that the number of co-op assignments (or rotations) is a significant predictor of retention. They also found that contextual support through mentorship is particularly influential for women undergraduate engineering students, such that co-op experiences can potentially help retain a diverse engineering student body.

Employment Returns to Participation in Cooperative Education Programs

Co-op experiences can also help bridge the transition between academia and professional practice by providing early socialization experiences for students. Through early exposure to work environments, students develop professional networks and professional role identities and gain cultural capital from which they can draw for future engineering contexts (Callanan and Benzing 2004; Gunderson et al. 2016; Korte et al. 2008; Kovalchuk et al. 2017; Parsons et al. 2005). In interviews with 21 engineering graduates, Kovalchuk et al. (2017) noted that students described co-ops as helping to clarify their career preferences and providing a path to full-time employment in engineering. Similarly, Anderson et al. (2012) surveyed students across 12 Canadian institutions about their participation in co-op programs, and found that co-ops helped students to align their academic and career goals and to feel more prepared for postgraduation work. Further, Raelin et al. (2014) found co-op experience to be associated with significant increases in students' work self-efficacy from their second to fourth year of college. Thus, co-op experiences have an important role in facilitating early employment entry or inadvertently gatekeeping these early field-specific work opportunities.

That said, not all students who major in engineering pursue engineering careers (Amelink and Creamer 2010; Lichtenstein et al. 2009; Sheppard et al. 2014). Thus, it is important to consider students' career intentions when discussing meeting STEM workforce needs. Analyzing surveys of 2143 junior and senior engineering students at 21 institutions, Sheppard et al. (2014) found that fewer than 30% of engineering students identified having engineering-only postgraduation plans, while 65% were open to both engineering and nonengineering career pathways. Women reported considering nonengineering pathways at higher rates than men, and further analysis showed that men were more likely than women to be employed in engineering occupations postgraduation. Among science and engineering graduates, women are slightly more likely to work in nonscience/engineering occupations (48% versus 42%; NCSES 2019). Notably, students with engineering-focused plans reported greater exposure to engineering through co-ops and internships (Sheppard et al. 2014), suggesting that co-op experiences can create environments that support and shape engineering career intentions. Women co-op participants described their co-op experiences as helping them prepare for their full-time jobs and increasing their confidence in their ability to succeed in the engineering workforce (Gunderson et al. 2016).

Previous studies have identified additional employment outcome benefits to co-op participation, including development of soft skills, a higher number of interviews during the job search, increased likelihood of a job offer prior to graduation, higher starting salaries, and smoother transitions from college to the workplace (Blair et al. 2004; Kovalchuk et al. 2017; Schuurman et al. 2005, 2008). Schuurman et al. (2005) analyzed college senior exit surveys from 900 graduating seniors using analysis of variance to compare groups of students with different levels of work experience. They found that those who participated in credited work experiences (e.g., co-ops) reported higher starting salaries than other students. Those with more work experience also reported more on-campus and on-site interviews, as well as more job offers, than students with no work experience. Furthermore, their results suggest that women benefit more from credited work experience than their male peers. However, Schuurman, et al. (2005) included only GPA as a covariate in this analysis, such that there may be issues with omitted variable bias, as other factors may have influenced the observed effects of work experience. Schuurman et al. addressed this issue in a subsequent study (2008) using 1479 senior exit surveys by including additional covariates (gender and engineering major) in their regression analyses. They found that work experience is positively associated with the likelihood of securing a job prior to graduation and a higher starting salary.

Diversity in Engineering: Co-op Participation and Outcomes of URM Students

Previous research focusing on co-ops and diversity in engineering have tended to primarily discuss the differences in outcomes between men and women. We thus extend previous work by focusing on co-op participation and outcomes of URM students. Main et al. (2020) found that Asian and URM students are less likely than their majority peers to participate in co-ops, but that the participation rates can vary by student race/ethnicity across engineering discipline. Investigating why URM students may be less likely to participate in co-ops, Johnson and Main (2019) interviewed URM engineering students about their perceptions of co-ops and their decisions about whether or not to participate in co-op. They found that URM students generally viewed co-ops positively and valued the work experience and commitment to one company that co-ops provide. Many interview participants also indicated that minority engineering organizations and programs were useful sources of information. Peers and upperclassmen from minority engineering programs provided valuable advice regarding the benefits and disadvantages of co-ops. Similarly, Lee and Matusovich (2016) found that engineering student support centers, such as minority engineering programs, can influence students' professional development by providing students with information about career opportunities, including internships, co-ops, and full-time jobs.

Participation in co-ops may also be relatively more advantageous for URM students. In analyzing data on co-op participation across six institutions, Ramirez et al. (2015) found that co-op participation is positively associated with the likelihood of graduating in engineering, with the greatest increase in likelihood among URM students who participate in co-ops.

Strayhorn and Johnson (2016) evaluated what URM engineering students learned from co-ops and internships using a survey of 1150 engineering undergraduates and subsequent interviews with 10 URM engineering students. They found that URM co-op/internship participants reported greater learning gains than nonparticipants in terms of problem-solving, soft skills, and career knowledge. They also showed that co-op/internship experiences facilitated URM students' learning about engineering as a profession.

Undergraduate work experiences can shape career-related decisions by modifying (or strengthening) students' perceptions of the field. This is particularly important for URM students because URM science and engineering graduates are slightly more likely to work in nonscience/engineering occupations compared to their White peers (49% versus 46%; NCSES 2019). Moreover, Melguizo and Wolniak (2012) found that STEM URM students who obtained jobs in a field closely related to their major, as opposed to a job less congruent with their major, are more likely to earn relatively higher salaries. They describe the importance of providing career services to students to help them navigate employment pathways. Co-op participation can be considered as one such pathway to a professional engineering career.

While previous research has suggested positive effects of co-op participation on student academic and employment outcomes, conclusions from most studies have been drawn based on analyses of self-reported survey data or interviews and comparisons between co-op participants and nonparticipants without addressing potential systematic differences between the two groups. Moreover, there is still a lack of understanding of the factors that influence co-op participation. Co-op programs have minimum GPA and other eligibility requirements, which means the academic and employment benefits associated with co-op participation may be due to the selection of higher-achieving students into these programs. To a large extent, existing research on the effects of co-op participation has been based on general comparisons of post-co-op outcomes between co-op participants and nonparticipants without explicitly accounting for the nonrandom selection into voluntary co-op programs. Therefore, there is a need to address selection issues in order to quantify the academic and employment returns to co-op programs. Our study contributes to the understanding of participation in and influence of co-ops by leveraging information about students' characteristics prior to co-op participation. This information allows us to form a meaningful comparison group to co-op participants by balancing participants and nonparticipants on the propensity of participation, which enables causal interpretation of our estimates. Further, we are able to determine gender-specific or race/ethnicity-specific responses to co-op participation. In regard to diversity in engineering, previous research has tended to focus on gender differences in co-op outcomes, and less so on the experiences of URM students. Thus, our study contributes to understanding how co-ops and similar work experiences may impact the outcomes of different groups of students. In so doing, the knowledge derived from these findings will help students and co-op program administrators to better assess the academic and employment returns to participation, and to develop strategies to enhance opportunities for URM engineering students toward promoting increased diversity in the engineering workforce.

Conceptual Framework

Our study is informed by Terenzini and Reason's model of influences on student learning and persistence (Terenzini and Reason 2005), a framework designed to help us understand the influence of the college experience on educational outcomes of interest. The framework consists of four main constructs: student precollege characteristics and experiences,

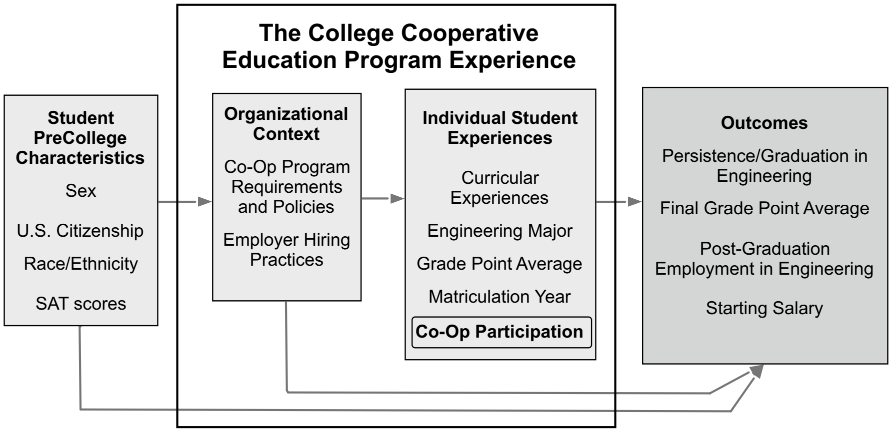


Fig. 1 Conceptual model of the influence of co-op participation on academic and employment outcomes (adapted from Terenzini and Reason 2005; Reason 2009; and Main et al. 2020)

organizational context, peer environment, and individual student experiences. We applied Main et al.'s (2020) adaptation of this framework to examine the impact of co-op participation, with the addition of SAT scores and employment outcome variables (see Fig. 1). The covariates, sex, race/ethnicity, U.S. citizenship, and SAT scores represent precollege characteristics. Organizational context encompasses co-op program requirements and policies and employer hiring practices. The organizational context was not specifically investigated in the empirical models, as this is a single-institution study. However, we included student engineering major in the models to account for potential differences in co-op placement by engineering discipline (e.g., Main et al. 2020). We also provide more information about the context of the research institution in the next section, as research findings may have the potential to be transferable to other similar institutional contexts. Individual student experiences include student's GPA, engineering major, curricular experiences (as measured by course grade), and matriculation year. Co-op participation is the key student individual student experience variable of interest. We considered the following educational and employment outcomes: graduation in engineering, final GPA, post-graduation job in engineering, and post-graduation starting salary. We describe our variables in the context of the conceptual framework in the next section.

Data and Research Context

Research Context

Our sample comes from a large research-intensive university in the Midwest with a highly ranked undergraduate engineering program. The university student population is predominantly White (72%). International students comprise 15% of the undergraduate engineering student population. The overall engineering graduation rate at this university is relatively high (greater than 75%). The voluntary co-op program at this institution is well-established, with partnerships with more than 500 employers. Approximately 21% of the engineering students participate in co-ops, which is slightly higher than the participation rates at the seven academic institutions examined by Barry et al. (2015). Students can choose between three-semester and five-semester rotation options, with each rotation occurring at the same company. Co-op students receive increasing salaries, as well as increasing work responsibilities, with each additional rotation. Since this is a voluntary co-op program, students must submit applications in order to be considered for placement with a co-op company. To be eligible for the application process, engineering students must have a minimum 2.60 GPA. The application process is similar for the five-semester and three-semester options, although students typically apply during their first year of study for the five-semester option, whereas students typically apply during their second year of study for the three-semester option. Thereafter, employers review applications and some invite selected students for on-campus interviews. Co-op placements are thus based on the student's academic achievement, including the minimum GPA requirement, as well as their application materials and interview performance. Importantly, co-op placement is also dependent on the number of positions available, which can vary by discipline (e.g., Main et al. 2020). On average, approximately 60% of applicants obtain co-op placements, but this rate varies by year and by engineering discipline.

Data Description

We collected data from three sources: (1) the university registrar's office, (2) the co-op student services office, and (3) the career services office. The registrar's office provided academic transcripts for all students enrolled from 1999 through 2017, the co-op student services office shared student application and placement information for the same time period, and the career services office provided postgraduation early career outcomes, including job placement information and starting salaries for the years 2003 through 2017. The career services office distributes the survey on employment outcomes annually, and while the number of respondents varies each year, the response rate is relatively high, ranging from 85 to 90%.

Our sample is therefore composed of undergraduate students who were enrolled in the school's College of Engineering between Fall 1999 and Fall 2010. The engineering disciplines in our sample include aerospace, chemical, civil, computer, electrical, industrial, and mechanical engineering, as well as a number of smaller enrollment majors, such as biomedical and materials engineering, which we group into a category of "Other Engineering Majors." We observed student academic records through August 2017, by which time students from the last cohort, Fall 2010, would be expected to have completed their degree (as measured with a six-year graduation rate; Ohland et al. 2011). Thus, we were able to observe students' academic records throughout their undergraduate engineering study, as well as their transition into postgraduation employment, by using the data from the career services office. We describe our variables in the next section in the context of our conceptual framework.

Conceptual Framework and Associated Variables

Consistent with the "precollege characteristics" of our conceptual framework, we collected the following demographic information: sex, U.S. citizenship, race/ethnicity, and SAT reading and math test scores. The registrar's office records sex as a binary variable (female or male) and records students' race/ethnicity as one of the following: American Indian or Alaska Native; Asian; Black or African American; Hispanic/Latino;

International; Native Hawaiian or Other Pacific Islander; White; or “2 or more races.” It also reports non-U.S. citizens as international students in a single group without identification of race/ethnicity. We used SAT reading and math scores, which are measured on a scale of 200–800, as a proxy for precollege academic achievement. Prior to 2005, SAT scores were reported for “math” and “verbal.” Thereafter, SAT scores have been reported for math, critical reading, and writing. Because our study period spans this change, “SAT Reading” represents either SAT reading or SAT verbal, depending on the year the test was taken.

For the “Individual Student Experiences” component of our conceptual framework, we included as variables year of matriculation in the college of engineering, engineering major after the general first-year engineering program, combined GPA of math and physics courses taken during the first-year engineering program (for curricular experiences), and second semester cumulative GPA. To be eligible to participate in co-op programs, student applicants must have a GPA of 2.6 or above. Since most co-op applicants submit applications during their first or second year, we considered the cumulative GPA at the end of the second semester of study as a reasonable proxy for the student’s academic performance at the time of co-op application. Consequently, we limited our sample to students with second-semester GPAs at or above 2.6.

We consider co-op participation as our primary variable of interest. Students in our sample institution can choose to participate in a three-semester or a five-semester co-op. We obtained information about students’ co-op participation from both the university registrar’s office and the co-op office. If co-op students complete all of their respective co-op rotations, they receive a certificate of completion. Therefore, we categorized students as completing co-op if the registrar or the co-op office recorded them as having earned a co-op certificate. However, there are instances in which some students do not complete all of their co-op rotations. Students may leave the co-op program for a variety of reasons, including the student’s own choice (unspecified in the records), change in position availability (e.g., an employer may exit the partnership with the university partway through a student’s co-op program), or the student no longer meets the minimum GPA requirement. Co-op partial completion is therefore defined here as a student completing at least one co-op rotation, but not the full set of three or five rotations. Since each co-op rotation lasts several months, it is possible that partial participation may still influence students’ academic performance and employment outcomes. We categorized students as partially completing co-op if the registrar’s office recorded them as registered in at least one co-op rotation, or if the co-op office recorded them as dropping out of a co-op program.

We examined the effect of co-op participation on academic and employment outcomes. For academic outcomes, we investigated the effect of partial and complete co-op participation on (1) the likelihood of graduation (in any major); (2) the likelihood of graduation in an engineering major; (3) among engineering students who graduate, the final GPA; and (4) among engineering students who graduate, the time to degree, measured as the number of enrolled semesters. For employment outcomes, we investigated the effect of partial and complete participation on attainment of engineering job and starting salary. We defined engineering job based on the U.S. Bureau of Labor Statistics 2018 Standard Occupational Classification (U.S. Bureau of Labor Statistics 2018). We classified students as having taken an engineering or nonengineering job by analyzing job titles and through job descriptions on employer websites. We examined two salary outcomes: (1) the students’ annual salary adjusted for inflation to 2016 dollars, and (2) the students’ annual salary adjusted for inflation and cost of living using a state cost of living index with the U.S. average as reference (Missouri Economic Research and Information Center 2018).

Sample Descriptive Statistics

Table 1 presents descriptive statistics for demographic characteristics, engineering major, graduation status, and academic performance. The sample for the analyses on academic outcomes includes 8580 students who matriculated in engineering. The first three columns include all students in the sample, with Column 1 focusing on students who completed all of the rotations of their co-ops; Column 2 focusing on students who participated in co-ops, but did not complete all of their rotations; and Column 3 focusing on non-co-op students. Columns 4–6 include only those students who graduated in any major. Column 4 includes all co-op completers, Column 5 includes students who participated in co-ops partially, and Column 6 includes only non-co-op students. Of the full sample of 8580 students, 952 completed a co-op program, 832 partially participated in the co-op program, and 6796 never participated (see Table 1). Of the 8198 students who graduated college in any major, 952 completed co-ops, 779 partially participated in co-ops, and 6467 did not participate in co-ops.

Approximately 96% of the students in the sample graduated, which is common for a selective university (Melguizo 2008). Co-op students, both completers and partial participants, are predominantly male and White. Female students were slightly more represented among co-op students (22% of co-op completers compared to 18.5% of non-co-op participants), whereas international students were particularly underrepresented among co-op students (1.5% of co-op completers compared to 17.8% of non-co-op participants). African American/Black and Hispanic/Latino students comprised smaller proportions of co-op participants than non-co-op participants. Compared to students in other engineering majors, students from mechanical engineering (31.7%) and chemical engineering (18.1%) were more likely to participate in co-ops. Mechanical engineering students were also more likely to partially participate in co-ops (24.0%), along with students in "other" majors (26.7%), which include the smaller enrollment majors, such as biomedical engineering. Among students who graduated, co-op participants, on average, had slightly higher second-semester GPAs (3.5 vs. 3.3), SAT reading scores (611 vs. 596), and final GPAs (3.5 vs. 3.2) than nonparticipants. However, co-op participants also had longer time to graduation (5.1 years) compared to nonparticipants (4.4 years).

Table 2 presents descriptive statistics for the demographic characteristics, academic performance, and employment outcomes on the subset of the sample used to analyze the effect of co-op on employment outcomes. The sample size is 5221 because it includes the subset of students who graduated and also reported employment information to the career services office. The first column includes students who completed co-ops, the second column partial co-op participants, and the third column non-co-op participants. Of the 5221 students who provided employment information, 518 completed a co-op program, 235 partially participated in a co-op program, and 4468 did not participate in co-ops. Consistent with the descriptive statistics of Table 1, co-op students tended to have higher GPAs than non-co-op participants. Compared to nonparticipants (78.6%), a greater proportion of co-op participants (88.8%) obtained an engineering job upon graduation. Moreover, co-op participants on average earned higher salaries than nonparticipants (cost-adjusted \$73,631 vs. \$69,296, respectively).

Methods

To examine the effect of co-op participation on engineering student academic and employment outcomes, we estimated treatment effect models with co-op participation as the treatment. We assessed the effect of each dosage of treatment (complete and

Table 1 Descriptive statistics focusing on academic outcomes

Variable	All students in sample (%)			All students graduated (%)		
	Complete Co-op	Partial Co-op	Non Co-Op	Complete Co-op	Partial co-op	Non Co-Op
Sex						
Male	78.0	78.2	81.5	78.1	77.8	81.2
Female	22.0	21.8	18.5	21.9	22.2	18.8
Race/ethnicity						
White	88.2	78.0	69.4	88.2	77.8	69.7
Asian	5.6	8.3	7.0	5.6	8.6	6.9
Black or African American	0.8	1.4	1.3	0.8	1.2	1.2
Hispanic/Latino	1.3	2.9	2.2	1.3	2.7	2.2
International	1.5	7.0	17.8	1.5	7.3	17.7
Other races	2.6	2.4	2.3	2.6	2.4	2.2
Engineering major						
Aerospace	9.6	9.0	11.9	9.6	9.0	11.7
Chemical	18.1	8.8	10.5	18.1	8.6	10.8
Civil	12.1	5.9	8.5	12.0	5.9	8.6
Computer	4.8	5.4	9.4	4.8	4.9	9.2
Electrical	11.9	15.4	15.6	11.9	14.8	15.6
Industrial	5.8	4.8	8.3	5.7	4.9	8.5
Mechanical	31.7	24.0	24.5	31.8	24.0	24.3
Other	6.1	26.7	11.3	6.1	28.0	11.0
Graduation status						
Did not graduate	0.2	6.4	4.8	NA	NA	NA
Graduated	99.8	93.6	95.2	100	100	100
Did not Grad. in Engr	0.6	14.3	13.9	0.4	8.5	9.6
Graduated in Engr	99.4	85.7	86.1	99.6	91.5	90.4

Table 1 (continued)

Variable	All students in sample (%)			All students graduated (%)		
	Complete Co-op	Partial Co-op	Non Co-Op	Complete Co-op	Partial co-op	Non Co-Op
Academic performance						
Second-semester GPA (4.0 scale)				3.5	3.4	3.3
Math/physics GPA (4.0 scale)				3.5	3.5	3.3
SAT math (200–800)				681	689	682
SAT reading (200–800)				611	616	596
Final GPA (4.0 scale)				3.5	3.4	3.2
Time to graduation (Years)				5.1	4.7	4.4
N	952	832	6796	952	779	6467

Table 2 Descriptive statistics focusing on employment outcomes

Variable	Complete Co-op	Partial Co-op	Non Co-Op
Sex			
Male	78.4	77.0	75.8
Female	21.6	23.0	24.2
Race/ethnicity			
White	86.7	76.6	75.1
Asian	5.6	8.9	6.2
Black or African American	0.6	0.9	1.0
Hispanic/Latino	1.34	4.3	3.2
Other races	3.7	3.0	3.5
Engineering major			
Aerospace	4.8	8.5	9.6
Chemical	22.2	11.5	11.4
Civil	8.7	5.1	8.1
Computer	3.9	8.9	7.5
Electrical	10.2	15.8	10.3
Industrial	6.8	9.4	10.8
Mechanical	33.0	33.2	27.5
Other	10.4	7.7	14.8
Academic			
Second-semester GPA (4.0 scale)	3.5	3.4	3.4
SAT math (200-800)	683	685	690
SAT reading (200-800)	605	603	579
Average final GPA (4.0 scale)	3.5	3.3	3.3
Employment			
Employed in Engr	88.8	84.7	78.6
Salary ($)	70,876	69,958	67,766
Salary ($, cost-adjusted)	73,631	70,825	69,296
Total	518	235	4468

partial participation) on our outcomes of interest. Inferring the effect of co-op participation on academic and employment outcomes requires evaluating what the student's outcomes would have been had they not participated in co-op programs and the difference between the observed outcome and the counterfactual. We performed this evaluation using the standard potential outcomes framework (Rubin 1974). Let D denote the binary treatment, with $D_i = 1$ if student i participated in co-op during college, and $D_i = 0$ otherwise. The potential outcomes are defined as $Y_i(D_i)$, and the treatment effect of student i is given by

$$\tau_i = Y_i(1) - Y_i(0). \tag{1}$$

Since for each student i, only one of the two potential outcomes was observed, that is, the student either participated or did not participate in co-op, we estimated the average treatment effect on the treated (ATT) to infer the effect of co-op participation on the academic and employment outcomes. Thus, we estimated the average realized gross gain of participants.

Since we could not observe the counterfactual mean outcomes of the treated (the academic and employment outcomes of co-op participants had they not participated in the co-op programs), we needed to choose an appropriate control group that best approximated the counterfactual outcomes. Simply using the mean outcomes from nonparticipants would have led to a selection bias in estimating the ATT, because it was possible that certain factors that informed whether a student participated in co-ops also would influence our outcomes of interest. In other words, the outcomes of the treated and the control group may have differed even in the absence of the co-op programs. Moreover, ordinary least squares estimation of the ATT with all of the individuals in the control group is sensitive to misspecification and could be driven by the outcomes of the control group when the control group is much larger than the treated group (Imbens 2015).

We constructed the counterfactual outcomes using propensity score matching (PSM) to adjust the balance between co-op participants and nonparticipants based on observed pretreatment information. This method, proposed by Rosenbaum and Rubin (1983), uses the conditional probability of assignment to the treatment given the covariates to adjust the sample and create counterfactuals for the outcomes with the treatment. If X_{i} is a vector of covariates, we can estimate the ATT as:

$$\tau_{ATT} = \tau|\left(D_i = 1\right) = E\left[E\left(Y_i|p\left(X_i\right), D_i = 1\right) - E\left(Y_i|p\left(X_i\right), D_i = 0\right)|D_i = 1\right] \quad (2)$$

where $p\left(D_i\right) = \Pr\left(D_i = 1|X_i\right) = p(X_i)$ is the propensity score. Rosenbaum and Rubin (1983) have shown that if, conditional on X_i, the potential outcomes are independent of the treatment assignment, then they are also independent of the treatment conditional on $p(X_i)$.

In effect, PSM was a method of strategically subsampling students who participated and students who did not participate in co-ops. Differences in the observed outcome variables were calculated from the participants and matched nonparticipants, with the average differences representing the effect of co-op participation. PSM relies on a fundamental assumption that selection into the treatment, in our case co-op participation, depends on observable covariates, such that conditional on the covariates, the potential outcomes are independent of the treatment: $Y_i(1), Y_i(0) \perp D_i|X_i$ (i.e., the unconfoundedness assumption). With conditional unconfoundedness satisfied, the estimated ATT can be interpreted as a causal effect.

While the unconfoundedness assumption is not testable, we followed Imbens (2014) to assess the plausibility of this key assumption by estimating the ATT using a pseudo outcome: second semester engineering GPA. Since this variable is observed pretreatment, our treatment should not have any effect on it, and an insignificant ATT on this pseudo outcome supports the unconfoundedness assumption. Results of the assessment are presented in Table 7. Since the estimated ATT on second-semester engineering GPA is close to zero and statistically insignificant, it provides evidence that this assumption is plausible within the scope of our study. Another important assumption, the overlap assumption, requires that $0 < p\left(D_i\right) < 1$.

According to summary statistics in Tables 1, 2 and 3, the treated and control groups are not balanced in terms of the observed covariates. There may exist systematic difference between the two groups, which would yield biased estimates if we were to directly estimate the treatment effect. The propensity score is used to group the treated and control units such that the conditional distribution of the covariates given the propensity score is the same for the treated and control groups; that is, the observed covariates of the two groups pre-treatment are comparable. We are thus able to draw meaningful inferences on the effect of co-op by comparing the outcomes of the two groups.

Balancing by the Propensity Score

To compare academic and employment outcomes between co-op participants and non-participants, we first needed to ensure that the factors that influence co-op participation are comparable between the two groups. The density plots displaying the propensity score overlap between treatment and control groups are shown in Fig. 2 for the academic outcomes sample and in Fig. 3 in the Appendix for the employment outcomes sample. Figure 2a presents the kernel density of the propensity score of complete co-op participation for the treated ("Co-Op") and control ("Non-Co-Op") groups. The distributions of the propensity score are distinctly different between the two groups. The control group peaks around 0.02, whereas the treatment group is centered around 0.15. In other words, co-op participants were more likely to participate in co-op in their undergraduate years than nonparticipants conditional on their demographic, major, and pre-co-op academic performance. Figure 2b presents the density plots of the treatment groups after we match on the propensity score. The distributions of the propensity score are almost identical across treatment groups, indicating that the matching is effective. Moreover, there are no longer significant differences in terms of mean, variance ratio, and distribution of the covariates between the treated and control groups. Thus, the two groups are reasonably comparable.

Following Rosenbaum and Rubin (1983), we used a probit model to estimate the propensity scores. While propensity score matching provides a credible alternative to experimental design, there are potential limitations stemming from the selection of matching variables. Previous studies have shown that the results of the treatment effect can be sensitive to the matching variables chosen (Dehejia and Wahba 2002). We addressed this by using evidence from previous research and guidance from our conceptual framework to inform our covariate selection. We included the demographic variables, academic variables, and standardized test (SAT) scores presented in Tables 1 and 2 to predict the conditional probability of participating in co-ops. Specifically, these variables included sex, race/ethnicity, U.S. citizenship, engineering discipline, linear and quadratic terms of second semester GPA, linear and quadratic terms of average GPA in math and physics courses, total credits taken in math and physics courses, SAT math score, SAT reading score, and matriculation year. With the estimated propensity scores, we then constructed our control group using 1-to-1 matching. We matched each treated observation with one control observation that had the closest propensity score (randomly selecting one observation in the case of ties in the closest propensity score.)

In the analyses below, we estimated the overall effects of co-op (across all students), as well as the effects of co-op on subsamples of students by gender and race/ethnicity, on our outcomes of interest: graduation in engineering, final GPA, postgraduation job in engineering, and postgraduation starting salary. Due to the small sample sizes of Black/African American and Hispanic/Latino students, we combined them into one URM group along with the category "Other Races."

Results

Demographic and Academic Achievement Factors Associated with Co-op Participation

To address the first research question on which demographic and academic achievement factors are associated with co-op participation, Table 3 reports the estimated coefficients of the probit model for the propensity of participating in co-ops. Across both levels (complete and partial) of co-op participation, we did not find statistically significant differences in the likelihood of co-op participation between male and female students. Compared to White engineering students, Asian and Hispanic/Latino engineering students are less likely to participate in co-ops to completion. However, there is no difference in the likelihood of co-op participation between African American/Black and White students. Meanwhile, international students are less likely than students with U.S. citizenships to participate in co-ops.

As can be expected given the variation in co-op placement opportunities by engineering major, we also found that there are differences in likelihood of participation by engineering department. Compared to mechanical engineering students, students from aerospace, computer, and industrial Engineering are less likely to participate in co-ops. Since we are investigating voluntary co-ops that consider GPA as part of the application process, academic achievement also plays a role in co-op participation. Students with higher second semester GPAs are more likely to participate in co-ops to completion. Higher SAT math scores are negatively associated with co-op participation, but the magnitude is very small.

Co-op Participation and Academic Outcomes (Graduation, Final GPA, and Time to Degree)

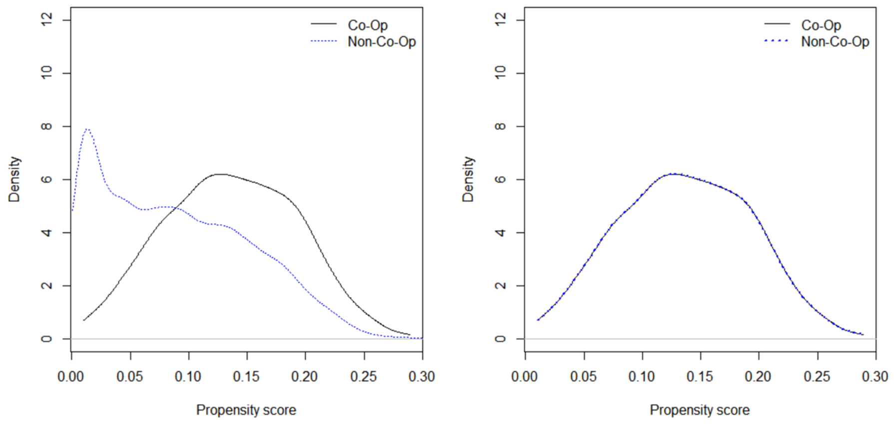
Our second research question asked, "Are co-op students more likely than non-co-op students to graduate in any major, persist in an engineering major, and earn higher final GPAs? Are there differences in these outcomes by gender and race/ethnicity?" Table 4 shows the estimated effects of co-op on the likelihood of graduating from college in any major and the likelihood of graduating in an engineering major using the matched samples described in the methods section. These analyses focus on the sample of 952 students who completed a co-op program and the sample of 832 partial co-op participants with their respective matched control groups of nonparticipants. We estimated the overall effect across all students in the sample, and also estimated the effect on subsamples disaggregated by sex and race/ethnicity. We provide three comparisons to show potential differences by dosage of co-op treatment: complete co-op participation versus no participation, partial co-op participation versus no participation, and complete co-op participation versus partial co-op participation.

Overall, completing co-op rotations versus nonparticipation increases students' likelihood of graduating from college in any major by approximately 3% and of graduating in an engineering major by approximately 10%. This is consistent across subgroups of students—male, female, and Asian/White. Although we did not find a statistically significant effect of completing co-ops on the likelihood of graduating in any major for URM students, co-op completion versus nonparticipation increases the likelihood of graduating in an engineering major by approximately 10% among URM students.

Table 3 Estimation of propensity to participate in co-op treatment

	All students		Students who graduated	
	Complete Co-Op	Partial Co-op	Complete Co-Op	Partial Co-op
Demographic factors				
Female	0.098	0.092	0.080	0.109
	(0.090)	(0.094)	(0.092)	(0.098)
Asian	− 0.338**	0.118	− 0.330**	0.147
	(0.155)	(0.141)	(0.156)	(0.145)
Black or African American	− 0.532	0.331	− 0.461	0.142
	(0.383)	(0.320)	(0.389)	(0.368)
Hispanic/Latino	− 0.829***	0.388*	− 0.760**	0.248
	(0.309)	(0.230)	(0.312)	(0.245)
International	− 2.778***	− 0.725***	− 2.815***	− 0.808***
	(0.280)	(0.156)	(0.280)	(0.159)
Other races	− 0.096	− 0.168	− 0.084	− 0.157
	(0.224)	(0.245)	(0.227)	(0.255)
Engineering major				
Aerospace	− 0.513***	− 0.308**	− 0.500***	− 0.293**
	(0.131)	(0.144)	(0.132)	(0.149)
Chemical	0.185*	− 0.270*	0.168	− 0.322**
	(0.112)	(0.148)	(0.112)	(0.153)
Civil	0.181	− 0.303*	0.163	− 0.318*
	(0.126)	(0.169)	(0.127)	(0.175)
Computer	− 0.860***	− 0.565***	− 0.850***	− 0.665***
	(0.171)	(0.175)	(0.171)	(0.188)
Electrical	− 0.291**	0.103	− 0.290**	0.047
	(0.124)	(0.124)	(0.124)	(0.130)
Industrial	− 0.285*	− 0.344*	− 0.317*	− 0.364*
	(0.165)	(0.185)	(0.166)	(0.189)
Other	− 1.011***	0.789***	− 0.990***	0.851***
	(0.154)	(0.111)	(0.154)	(0.113)
Academic performance				
Second-term GPA	12.441***	1.815	12.071***	1.785
	(1.833)	(1.716)	(1855)	(1.794)
Math/Physics GPA	0.928	1.897***	1.039*	2.041***
	(0.617)	(0.637)	(0.623)	(0.661)
SAT math	− 0.002**	0.001	− 0.002**	0.0004
	(0.001)	(0.001)	(0.001)	(0.001)
SAT reading	− 0.0004	0.001**	− 0.0002	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
N	7748	7628	7419	7248

*p < 0.1; **p < 0.05; ***p < 0.01. Standard errors in parentheses. Quadratic terms of Second-term GPA and Math/Physics GPA, and cohort (year of enrollment) are controlled for but not reported



(a) Pre-matching **(b) Post-matching**

Fig. 2 Kernel density of propensity score of co-op participation pre- and post-matching of the academic outcomes sample

Table 4 Likelihood to graduate in any major and in engineering by co-op status

	Overall effect	Male	Female	Asian/White	URM
Average treatment effect on the treated					
Complete Co-op vs. Non Co-op					
Likelihood to gtraduate in any major	0.032***	0.032***	0.029***	0.031***	0.034
	(0.006)	(0.006)	(0.01)	(0.006)	(0.02)
Likelihood to graduate in Engr	0.097***	0.096***	0.098***	0.096***	0.103***
	(0.01)	(0.011)	(0.017)	(0.01)	(0.034)
N	1904	1486	418	1786	90
Partial Co-op vs. Non Co-op					
Likelihood to graduate in any major	– 0.019*	– 0.025**	0.0001	– 0.018	– 0.081***
	(0.011)	(0.012)	(0.019)	(0.012)	(0.031)
Likelihood to graduate in Engr	0.01	0.011	0.003	0.004	– 0.044
	(0.017)	(0.019)	(0.029)	(0.018)	(0.049)
N	1664	1302	362	1436	112
Marginal effect of Co-op completion					
Complete vs. Partial Co-op					
Likelihood to graduate in any major	0.067***	0.068***	0.065***	0.067***	0.069***
	(0.008)	(0.009)	(0.014)	(0.009)	(0.028)
Likelihood to graduate in Engr	0.18***	0.179***	0.181***	0.179***	0.186***
	(0.013)	(0.014)	(0.021)	(0.013)	(0.043)
N	1664	1302	362	1436	112

*p < 0.1; **p < 0.05; ***p < 0.01. Standard errors in parentheses

Table 5 Academic outcomes of students graduated in engineering by co-op status

	Overall effect	Male	Female	Asian/White	URM
Average treatment effect on the treated					
Complete Co-op vs. Non Co-op					
Overall GPA	0.096***	0.094***	0.104***	0.099***	0.01
	(0.016)	(0.017)	(0.027)	(0.017)	(0.054)
Time to degree	0.803***	0.808***	0.783***	0.801***	0.908***
	(0.019)	(0.02)	(0.032)	(0.019)	(0.063)
N	1892	1476	416	1774	90
Partial Co-op vs. Non Co-op					
Overall GPA	− 0.001	− 0.013	0.043	− 0.015	− 0.002
	(0.021)	(0.023)	(0.036)	(0.022)	(0.062)
Time to degree	0.416***	0.459***	0.26***	0.448***	0.516***
	(0.036)	(0.038)	(0.06)	(0.037)	(0.103)
N	1426	1118	308	1222	90
Marginal effect of Co-op completion					
Complete vs. Partial Co-op					
Overall GPA	0.074***	0.072***	0.081***	0.076***	− 0.013
	(0.017)	(0.018)	(0.028)	(0.017)	(0.056)
Time to degree	0.27***	0.275***	0.25***	0.268***	0.375***
	(0.028)	(0.03)	(0.047)	(0.029)	(0.094)
N	1426	1118	308	1222	90

*p < 0.1; **p < 0.05; ***p < 0.01. Standard errors in parentheses

While participating in co-ops to completion increases the likelihood of graduating in engineering, we did not find similar effects from partial co-op participation. There appears to be no difference in the likelihood of graduating in an engineering major between students who partially participate in co-ops and nonparticipants. Rather, we found evidence that partial co-op participation decreases the likelihood of graduating in any major, particularly for male and URM students. Comparing co-op participants who completed all rotations with those who partially participated, we found that those who completed co-ops are more likely to graduate in any major by approximately 7% and more likely to graduate in an engineering major by approximately 18%. This is consistent across all subgroups of students.

Table 5 reports the estimated effects of co-op participation on final GPA and time to degree among students who graduated in an engineering major.[1] Among students who graduated in an engineering major, those who completed co-ops earned final GPAs that are on average 0.1 points higher than non-co-op participants. This finding is consistent across subgroups of students, except for URM students where there is no difference in final GPAs between co-op completers and nonparticipants. As can be expected given the additional time needed to complete co-op rotations, time to degree is extended by about 0.8 years for

[1] We also performed the same analyses on the sample of students who graduated in any major, and the results are largely consistent across the two sets of samples.

co-op completers compared to nonparticipants, which translates to roughly two semesters.[2] For URM students, time to degree is extended slightly longer, by about 0.9 years between co-op completers and nonparticipants.

While partial co-op participation compared to nonparticipation did not increase final GPAs on average, it added 0.4 years on average to the total time to degree. Comparing students who completed co-op to those who partially participated, completing the co-op program increases the overall GPA by 0.7–0.8 points in all but the URM group, where it makes no difference. Again, co-op completion versus partial participation increases time to degree, but by approximately one semester (0.3 years).

Co-op Participation and Employment Outcomes (Engineering Job and Starting Salary)

We examined the effect of complete and partial co-op participation on employment outcomes in addressing our third research question, "Are co-op students more likely than non-co-op students to obtain postgraduation jobs in engineering and to earn higher starting salaries, and are there differences by gender and race/ethnicity?" Table 6 shows the estimated effects of co-op participation on the likelihood of obtaining an engineering job postgraduation and on starting salaries (with and without cost of living adjustment by state). Compared to non-co-op participants, completing co-ops increases the likelihood of attainment of an engineering job post-graduation by 6% across all students. However, we did not find similar significant effects among the subgroups of female and URM engineering students. Engineering students who completed co-ops had a higher average starting salary by about $2805 ($3908, cost adjusted) than those who did not participate. URM engineering students showed greater gains from co-op completion—URM students who completed co-ops earned, on average, $6886 (and $10,176 cost-adjusted) higher starting salaries than URM students who did not participate in co-ops.

Results from the analyses of partial co-op participation versus non-participation indicate that partial participation has no significant effect with respect to the measured employment outcomes. That is, partial participation did not significantly affect the likelihood of obtaining an engineering job postgraduation or starting salaries for any subgroup of students. The gains in employment outcomes appear to be limited to co-op completion. Comparing students who completed all of their co-op rotations versus those who partially participated in co-ops, completing the co-op program is associated with higher average starting salaries by about $3278 ($5911, cost-adjusted), and this seems to be consistent across subgroups of students.

Discussion

To understand more fully the impact of co-ops, we began our investigation by examining whether there are differences in participation by student gender and race/ethnicity. Using Main et al.'s (2020) adaptation of Terenzini and Reason's (2005) model of influence on student learning and persistence, we identified the key covariates in terms of student pre-college characteristics and individual experiences that are relevant to co-op participation. We found that women are just as likely as men, and African American/Black engineering

[2] In our analysis, the Spring and Fall semesters are each equivalent to 0.4 year, while the Summer session is equivalent to 0.2 year.

Table 6 Employment outcomes of students graduated in engineering by co-op status

	Overall effect	Male	Female	Asian/White	URM
Average treatment effect on the treated					
Complete Co-op vs. Non Co-op					
Likelihood of	0.064***	0.068***	0.050	0.074***	– 0.031
Engineering job	(0.022)	(0.023)	(0.037)	(0.022)	(0.067)
Salary ($)	2804.56***	2576.59***	3635.55***	2669.00***	6886.19***
	(747.23)	(796.98)	(1255.61)	(760.26)	(2346.15)
Salary	3907.97***	3949.27***	3757.87**	3699.51***	10,175.94***
($, cost adjusted)	(813.52)	(867.97)	(1359.64)	(825.93)	(2738.60)
Likelihood of job	0.080**	0.054	0.197***	0.077*	0.153
Out of state	(0.039)	(0.041)	(0.070)	(0.040)	(0.128)
N	1032	804	228	966	66
Partial Co-op vs. Non Co-op					
Likelihood of	0.030	0.017	0.073	0.039	– 0.079
Engineering job	(0.035)	(0.037)	(0.057)	(0.036)	(0.089)
Salary ($)	1139.91	1765.54	– 921.81	665.00	1535.60
	(1070.45)	(1146.87)	(1738.91)	(1108.37)	(2781.48)
Salary	1892.54	2071.18	1303.87	1915.61	– 51.71
($, cost adjusted)	(1256.31)	(1349.81)	(2046.60)	(1307.58)	(3281.41)
Likelihood of job	0.161***	0.170***	0.123	0.156**	0.202
Out of state	(0.061)	(0.065)	(0.104)	(0.063)	(0.144)
N	468	363	105	430	38
Marginal effect of Co-op completion					
Complete vs. Partial Co-op					
Likelihood of	0.047	0.038	0.086	0.058*	– 0.132
Engineering job	(0.031)	(0.033)	(0.055)	(0.031)	(0.092)
Salary	3277.89***	2497.82*	6834.10***	3006.87**	8698.35**
	(1220.45)	(1280.96)	(2202.09)	(1234.01)	(4042.54)
Salary ($)	5911.10***	5084.67***	9678.70***	5496.40***	14,205.10***
($, cost adjusted)	(1463.08)	(1537.30)	(2642.77)	(1476.88)	(4838.16)
Likelihood of job	– 0.071	– 0.100	0.098	– 0.070	– 0.110
Out of state	(0.059)	(0.061)	(0.117)	(0.059)	(0.257)
N	468	370	98	429	39

*p < 0.1; **p < 0.05; ***p < 0.01. Standard errors in parentheses

students are just as likely as White engineering students, to participate in co-ops. However, we also found that there are some demographic differences in the likelihood of participation. Asian American and Hispanic/Latino engineering students are less likely than White engineering students to participate in co-ops. Because our study relied on administrative data from the registrar and the co-op student services offices, we are unable to identify why there are differences in the likelihood of participation by race/ethnicity. Previous studies have shown that students, regardless of gender and race/ethnicity, tend to consider the benefits and disadvantages of co-op programs similarly when determining whether or not to pursue co-op opportunities (e.g., Ramirez et al. 2015; Johnson and Main 2019). Yet, there are differences in co-op participation by student demographic characteristics, suggesting that further research is needed to provide more insights regarding student decision-making regarding workforce preparation and to identify potential areas for intervention for increased interest in, access to, and/or placement in co-ops.

As proposed in our conceptual framework (Fig. 1), co-op program requirements and policies and employer hiring practices are critical elements in determining who participates in co-ops. The number of students who apply for co-ops, the number of interviews conducted by employers, and the number of students who are placed in co-ops vary by engineering department (Main et al. 2020). Altogether, this suggests that additional research should be conducted to examine how elements of the organizational context may or may not contribute to the diversity of students participating in co-ops. This may entail evaluating co-op placement procedures and policies, examining employer hiring practices, or investigating co-op recruitment and advertising efforts. Examining the role of the organizational context may uncover opportunities to broaden participation in co-ops. For example, focusing on URM students and the pathways to co-op participation, Johnson and Main (2019) highlighted the importance of minority engineering programs in encouraging African American/Black students to participate in work experience and extracurricular programs, such as co-ops. Promoting partnerships between co-op student services offices and minority engineering programs may therefore be a potential area for increasing interest and participation in co-ops among URM students. Thus, while our study provides evidence that there are differences in likelihood of participation by race/ethnicity, future work could investigate more fully elements of the organizational context that could potentially contribute to increasing the diversity of students participating in co-ops.

After all, who has access to and who participates in co-ops is particularly important given the positive academic and employment outcomes that have been identified with co-op participation. In terms of academic outcomes, co-op participation increases the likelihood of graduating in engineering for all groups of students, which is consistent with previous studies (Raelin et al. 2014; Ramirez et al. 2015; Samuelson and Litzler 2013). However, these benefits are associated only with completing all of the co-op rotations, rather than partial participation. Our results also show that co-op participation (versus nonparticipation) increases the likelihood of persistence by 10% among URM students. ASEE (2017) has reported lower engineering graduation rates among African American/Black and Hispanic/Latino students, and our findings suggest that co-ops can be an important avenue for helping URM students persist in engineering.

Among students who graduate in engineering, completing co-ops also increases final GPAs by about 0.10 points, on average, versus nonparticipation. We did not find similar results among URM students; that is, there is no difference in final GPAs between URM students who participate in co-ops and URM students who do not participate in co-ops. Similar to our results regarding likelihood of graduation in engineering, partial co-op participation is not associated with higher final GPAs. This suggests, on the one hand, that completion of all of the co-op rotations is critical to accruing the benefits of co-op participation. On the other hand, there may be differences in the unobserved experiences of partial co-op participants compared to co-op completers that could influence their outcomes. Approximately 21% of the engineering students at this institution participate in voluntary co-ops. Among students who are placed and begin co-ops, only 53% complete all of their rotations. Our data sources have relatively limited information regarding why some students do not complete their co-op rotations, and these can include changes in co-op position availability and student choice to leave the program. Because the gains from co-op participation are primarily seen among co-op completers, more research should be conducted to examine the reasons for non-completion and the experiences of co-op students toward identifying opportunities to potentially help encourage and promote completion of all rotations.

As can be expected, co-op participation extends time to degree. While co-op participation extends the length of time students take to complete their degrees, the average addition to the time to degree (two to three semesters) is less than the length of the co-op program, which is either three or five semesters. This may be due to co-op students taking more credit units while their classes are in session and/or non-coop participants participating in other programs that may lengthen their time to degree, such as study abroad. For students who might be discouraged from participating in co-ops because of the increased time to degree, this information could help allay some of their concerns regarding the relative extent of the program.

In terms of employment effects, we found that the benefits of co-op participation applied primarily to students who completed the program as opposed to those with partial participation. Co-op completers are more likely than nonparticipants to obtain engineering jobs and to earn, on average, higher starting salaries post-graduation. Our results are consistent with previous findings that the number of co-op work experiences a student completes is significantly associated with increased starting salaries (Schuurman et al. 2008). The higher starting salaries may be in part due to increased professional skills and engineering work-force knowledge gained through co-ops in combination with higher earnings associated with each additional co-op rotation completed. For many employers, co-ops provide an important recruitment tool, and the higher likelihood of obtaining an engineering job is likely partly related to co-op companies offering co-op students who have worked with them permanent positions post-graduation. This may help explain the difference in outcomes between partial participants and co-op completers, since completion of rotations may signal skills, behavior, commitment, and/or preferences that employers are seeking.

Our results also indicate that there is variation in the employment benefits of co-op participation by student subgroups. While URM co-op participants are more likely than URM nonparticipants to earn higher starting salaries, there does not appear to be an associated increase in the likelihood of attainment of an engineering job. However, our analysis on the employment outcomes of URM students entails a relatively small sample size, and therefore, we consider this to be suggestive evidence of a positive trend in the potential of co-ops to help improve salary outcomes among URM students. We find similar results among the subgroup of female students. Although female co-op participants are more likely to earn higher starting salaries than those without co-op experiences, female co-op engineering students are no more likely to obtain engineering jobs than female nonparticipants. Given the underrepresentation of women and URM in the professional engineering workforce, these findings regarding attainment of engineering jobs need to be further investigated with additional data on student career goals and job offers.

Study Limitations

While our study used a rich set of variables to address the selection issues in co-op participation and to identify the effect of co-ops on academic and employment outcomes, there are several limitations. In matching the treatment groups, we did not observe student intention for co-op programs or other potential relevant covariates unavailable in the administrative datasets. As such, even though we accounted for all relevant observed covariates as informed by our conceptual framework, the effectiveness of matching could have been improved with information regarding student interest. Nonetheless, our assessment of the unconfoundedness assumption (Appendix Table 7) provides some assurance that our data satisfy this assumption even without controlling for student intention. We collected and merged a robust dataset from three university sources, but, there are some limitations associated with data quality and availability. In defining co-op participation, we used data from two sources, the registrar's office and co-op student services office, to cross-check and to increase our accuracy in correctly identifying student participants. However, there were a very small number of observations that were inconsistent between the two data sources, such that it is possible that we may have misclassified some students in our sample.

Given our focus on diversity in engineering, we conducted several analyses using the subset of students who identified as URM in the registrar records. However, the sample size is relatively small, such that our findings focusing on URM students should be interpreted with caution. Nevertheless, the findings highlight important trends in co-op participation and outcomes by student subgroups that should be investigated further. Future work should expand the sample size by examining the effect of voluntary co-ops across multiple research institutions, which would also address the limitations associated with a single institution study. Co-op placement is a complex process and the organizational context has an important role in the participation and outcomes of students. While our study provides evidence of the impact of co-op programs while mitigating potential selection bias, further work needs to be conducted at a larger scale. In addition to entailing data from multiple institutions, this could also include examining the impact of similar interventions aimed at preparing students for the workforce. For example, we provide evidence regarding the dosage effects of co-ops showing that partial participation is not as beneficial as the completion of co-op rotations. Future studies should examine how co-op participation might compare with other professional work experience programs, such as internships, and whether participation in internships and other extracurricular activities leads to positive academic and employment outcomes, and whether there are differences by gender and race/ethnicity.

Conclusion and Implications

We examined student demographic and academic achievement factors that predict co-op participation, and the effects of co-op participation on academic and employment outcomes taking into account issues associated with selection bias. We applied propensity score matching to more credibly identify the academic and employment returns to co-op participation, extending the literature on the impact of work-intervention programs on student outcomes. We also further the literature by examining how the dosage of the treatment—that is, whether co-op participants complete their rotations or partially participate—influences student outcomes. Importantly, we investigated whether co-op participation and the associated outcomes vary by student gender and race/ethnicity in the context of the relatively low levels of diversity in engineering undergraduate programs and the engineering workforce.

We found that engineering student participation in voluntary co-ops, compared to non-participation, has a positive impact on the likelihood of persisting in engineering through graduation, on final graduation GPA, the likelihood of obtaining an engineering job postgraduation, and on starting salaries postgraduation. However, there are some differences in outcomes when we disaggregate our analyses by gender and race/ethnicity, primarily in terms of attainment of an engineering job, warranting further investigation into the causes of the uneven gains in employment outcomes by subgroups. Our results also show that Asian American and Hispanic/Latino engineering students are less likely than their counterparts to participate in co-ops, highlighting an important area for developing interventions to increase diversity in the composition of engineering graduates and professional engineers. Moreover, the benefits to co-op participation are limited to students who complete all of their co-op rotations, rather than partial participation, identifying another area for additional support to help improve engineering student outcomes.

Our findings can be applied in multiple ways. Co-op programs can use our findings to recruit students by sharing the benefits of participation, to develop strategies to increase access to co-ops for a wider range of students, and to develop supports for co-op participants to complete all of their rotations. Meanwhile, students can use this information to make more informed decisions regarding their academic trajectory and preparation for the workforce. Overall, our research findings support the value of co-op participation among engineering students in terms of academic and employment gains, and in potentially contributing to diversity in the engineering workforce. Our findings are likely applicable to other research institutions and other fields that offer similar work-related experiences to enhance and expand in-classroom learning.

Co-ops can provide a promising pathway to help increase student persistence in engineering and to improve subsequent employment outcomes. Co-ops can serve as an important bridge between academic study and professional engineering practice, such that who has access to these opportunities could play a role in the level of diversity in the engineering workforce. That is, co-ops could be considered as a "gatekeeper" to opportunities to gain not only early engineering work experience, but also to later joining the engineering professional workforce. Thus, in addition to having the potential to directly impact co-op recruitment efforts and practice, our study also has broader implications for increasing diversity in the engineering workforce.

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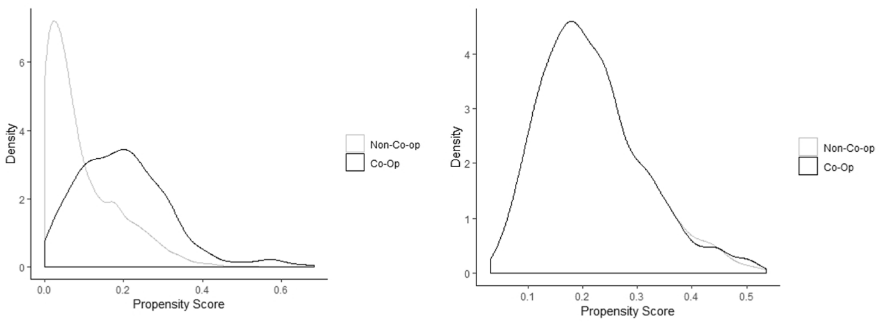
Appendix

See Appendix Fig. 3 and Table 7.



(a) Pre-matching **(b) Post-matching**

Fig. 3 Kernel density of propensity score of co-op participation pre- and post-matching of the academic outcomes sample

Table 7 Assessment of unconfoundedness assumption

	Overall effect	Male	Female	Asian/White	URM
Complete Co-op vs. Non Co-op					
Second semester Engr GPA	0.009	0.014	− 0.009	0.01	− 0.051
	(0.021)	(0.022)	(0.035)	(0.021)	(0.07)
N	1892	1476	416	1774	90
Partial Co-op vs. Non Co-op					
Second semester Engr GPA	0.021	0.012	0.055	0.033	− 0.045
	(0.025)	(0.027)	(0.042)	(0.026)	(0.075)
N	1426	1118	308	1222	90

Assessment of unconfoundedness assumption using pseudo outcome second semester GPA which is observed prior to treatment. Estimated average treatment effect on the treated close to zero and statistically insignificant suggests evidence that the assumption is plausible. *$p < 0.1$; **$p < 0.05$; ***$p < 0.001$. Standard errors in parentheses

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