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A Case for Disaggregating Engineering Majors in Engineering Education Research: The Relationship between Co-Op Participation and Student Academic Outcomes*

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Cooperative education (co-op) programs provide students with relevant professional experience while they pursue undergraduate degrees. While previous studies identified various benefits of voluntary co-op participation, many studies tend to aggregate engineering majors in their analyses. This study identifies departmental differences in student participation in co-ops and the associated likelihood of graduation using data from a research-intensive institution in the Midwest U.S. Logit regression models were used to estimate the likelihood of co-op participation and graduation in engineering, and ordinary least squares linear regression models were used to estimate the influence of co-op participation on time-to-graduation. At this institution, women are more likely than men to participate in co-ops in aerospace and industrial engineering. Co-op participation is positively associated with graduation except in industrial engineering. The number of enrolled semesters that co-op extends time-to-graduation varies by engineering major. Disaggregating engineering majors in examining co-op participation and outcomes shows important differences that reflect major-specific contexts. This study highlights the importance of disaggregating majors in examining the effects of academic and career preparation interventions on student outcomes in engineering education.

Keywords: cooperative education programs; academic outcomes; regression analysis; engineering majors; persistence

1. Introduction

In *Educating the Engineer of 2020*, the National Academy of Engineering notes the importance of improving the persistence of engineering students and the associated need to make learning experiences more meaningful to students. The report argues that "a disconnect between engineers in practice and engineers in academe has developed and grown" [1, p. 20]. Cooperative education (co-op) is a form of experiential education that provides engineering students with practical industry experience. Scholars have shown that co-ops can provide meaningful learning experiences, and thus, bridge the gap between academe and engineering practice [2, 3]. While previous research has documented a relationship between co-op participation and positive academic and employment outcomes, it is well known that co-op opportunities can vary across academic institutions and between voluntary and mandatory programs [4]. Furthermore, co-op opportunities and associated student outcomes could also vary by engineering major, yet many studies tend to aggregate analyses across engineering majors/departments. Because of the variation in co-op opportunities and paths to degree completion by engineering major, we propose that disaggregating analyses by engineering major could reveal major/department-specific differences in student participation and outcomes. We make a case for disaggregating engineering majors in examining the outcomes of academic programs and interventions by addressing the following research questions in the context of a voluntary cooperative education program at a single research-intensive institution in the Midwestern United States:

1. Which factors are associated with co-op participation by engineering major?
2. Is co-op participation associated with the likelihood of graduating in engineering (and in the same initial engineering major declared)?
3. Among students who graduate in engineering, does co-op participation increase time-to-graduation?

Our findings provide important, major-specific information useful to co-op administrators, co-op employers, and other stakeholders toward further improving or developing recruitment strategies for students by major. Research findings can also be informative for students determining what the potential academic returns may be to co-op partici-

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pation given their specific major. Importantly, we contribute to the engineering education literature by showing how results can vary when analyses are conducted in the aggregate versus disaggregated by engineering major. Engineering education researchers can potentially apply our findings to determine how contexts, such as engineering major, might influence their outcomes of interest and develop research designs and empirical strategies accordingly.

2. Background

2.1 Cooperative Education Programs and Differences across Engineering Majors

The National Commission for Cooperative Education defines co-op as a "structured educational strategy integrating classroom studies with learning through productive work experiences in a field related to a student's academic or career goals" [5, p. 17]. Co-op has been a staple of engineering education for more than 100 years, and numerous studies have documented its benefits on participants' academic performance, such as higher course grades and increased retention [6, 7]. Although previous studies have tended to aggregate analyses to include all engineering majors/departments, each engineering major is unique partially due to major-specific cultures, which can be encapsulated as "how we do things around here" [8, p. 8]. "How we do things around here" is a function of the engineering major/department, the academic institution, and the people and context within which it operates. These major-specific cultures may affect the prevalence of co-op opportunities, the relative level of student co-op interest and participation, and the potential employment trajectories of graduates.

Co-op opportunities tend to vary by engineering major – a survey conducted by the National Association of Colleges and Employers found that co-op employers chose schools from which to recruit based on the majors offered at that school [3]. Using survey data from a first-year engineering program and data from the corresponding institutional co-op office, Ramirez et al. found that potential co-op employers advertised for and interviewed engineering students based on student major [9]. Given major-specific requirements specified by co-op employers, students' engineering majors play an important role in the opportunities that are available. Further, schedule of course offerings, graduation rates, and time to degree can vary by engineering major, such that it is important to disaggregate student engineering majors when conducting analyses on undergraduate academic outcomes, as this study does [10–13].

2.2 Student Participation: Engineering Cooperative Education Programs

Previous studies have identified several factors that influence student participation in cooperative education programs [14–17]. Ramirez et al., for example, documented the reasons students participate in co-ops, including obtaining work experience, gaining a competitive edge in the workforce, receiving engineering-specific job training and networking, earning a salary, and having the opportunity to explore potential careers [9]. They also reported the reasons why students choose not to participate in co-ops, such as the increased time-to-graduation, concerns regarding missing other opportunities available on campus, and the potential for becoming disconnected with peers on campus or taking courses "off-sequence" from their engineering cohort. Anderson et al. found that students were influenced by their friends, institutional websites, emails from the institution, institutional recruiters, and professors [14]. Approximately 95% of co-op participants in their study indicated they were interested in co-ops because participation would ensure a "good job" after graduation. Many respondents cited the range of career opportunities related to their field of interest and the ability to explore career options as reasons for participating in co-ops [14].

There are also studies examining student participation in co-ops from the perspective of co-op employers. The 2016 National Association of Colleges and Employers (NACE) survey of employers shows that employers prioritize applicants who have higher grade point averages (GPAs) and leadership experience, as well as the relevance of the student's field of study, when selecting for placement in internship and co-op positions [3]. NACE's study emphasizes that employers are more likely to recruit and hire co-op students at colleges that offer instruction in a wider range of engineering disciplines. It also highlights the importance of engineering disciplines in a student's likelihood of co-op participation and subsequent post-graduation employment outcomes. Overall, in determining from which colleges to recruit, employers consider four main elements: perceived quality of the college's engineering program, the college's recruiting experience, the college's geographic location, and the specific engineering academic disciplines/majors the college offers.

2.3 Student Persistence: Likelihood of Graduation and Time-To-Graduation among Co-Op Participants

Engineering students gain several benefits from participating in co-ops, such as improved academic performance, learning outcomes, and subjective well-being [7, 16, 18, 19]. Blair et al. found that students who completed a three-term co-op program had higher GPAs than students who did not participate [7]. In addition to improved GPAs, Blair et al. also showed that co-op participation increased time to degree by about two terms among those who graduated [7]. Similarly, Ramirez et al. found a positive relationship between co-op participation and likelihood of graduating in engineering and the associated final GPA, using data from six institutions in the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) [16]. In this study, Ramirez and colleagues also noted disciplinary differences in the relationship between co-op participation and graduation, time-to-graduation, and final GPA. For example, co-op participants in aerospace engineering extended their average time to degree for a longer duration than co-op participants in mechanical engineering [16].

It is often proposed that co-op programs can help bridge the gap between education and engineering practice, and that co-ops can provide meaningful experiences that help promote persistence among engineering students [1–3]. Social and cognitive outcomes that have been associated with persistence in engineering include self-efficacy, work self-efficacy, professional role confidence, and contextual support. Self-efficacy is an individual's belief in their ability to complete a task [20], whereas work self-efficacy is an individual's belief in their ability to perform the social functions (e.g., teamwork, managing politics) required for success in the work place [21]. While our study does not address social and cognitive outcomes, it is important to note that they help explain the mechanisms by which cooperative education could potentially affect persistence in engineering. According to Lichtenstein, McCormick, Sheppard, and Puma, students who persist in engineering report more involvement in practicum, field experience, and co-op than those who do not persist [22]. Other research affirms that such experiences are formative, but may either affirm or discourage identification with engineering [23]. Seeking to explain the link between co-op experiences and persistence in engineering, Reisberg et al. show that cooperative education impacts work self-efficacy [24]. They surveyed all second-year students in the colleges of engineering from four universities and followed up with another survey on self-efficacy one year later. Their findings suggest that successful co-op experiences reinforce students' beliefs about their engineering abilities. Co-op students also report a significant increase in work self-efficacy from their second to third year of participation, while non-co-op students show a slight decrease in work self-efficacy during the same time period. Based on a third survey of these same students, Raelin et al. confirmed that work self-efficacy, which is strongly tied to students' participation in co-ops, was an important factor in student persistence [25].

2.4 Disaggregating Analyses by Engineering Major

Our study builds on previous engineering education research that highlights engineering major-based differences [e.g., 16, 26–29]. Parikh et al. analyzed data from the Academic Pathways of People Learning Engineering Survey (APPLES) to identify students' motivations in studying engineering [27]. The survey was distributed to over 4,000 juniors and seniors in mechanical, electrical, chemical, industrial, aerospace, and "biology-related" engineering majors across 21 institutions. Parikh et al. found that, when data across all majors were aggregated, women showed lower behavioral motivation than men. However, when they disaggregated by major, they found no significant difference between men and women in terms of behavioral motivation in electrical, chemical, aerospace, and "biology-related" engineering majors [27]. Women in industrial and mechanical engineering reported lower behavioral motivation than men in these respective majors. Meanwhile, Sheppard et al. found differences in the factors influencing student career trajectories across engineering majors [28]. Examining the APPLES data, as well as the National Survey of Recent College Graduates data, they highlight the importance of environmental and contextual factors – the student's experiences and the student's major – in determining students career pathways.

The likelihood that students will have engineering-focused career plans appears to vary by engineering major. More recent engineering education research by Lord, Ohland, Layton and Camacho documented differences in the graduation rate within the same engineering major, graduation rate from any engineering major, and graduation rate from the institution using data from 111,925 engineering students in chemical, civil, electrical, industrial, and mechanical engineering across 11 U.S. academic institutions [26]. This study also illustrates disciplinary differences in the pathways students take from matriculation through graduation, the rate at which a department/major graduates all students ever enrolled, and the rate at which a department/major attracts students to switch to their major [26]. While these studies found differences in outcomes by engineering major or discipline, it is important to note that programmatic and institutional contexts also play a role in the variation in outcomes.

Focusing on co-ops, Schuurman, Pangborn and

McClintic examined the relationship between the number of co-op semesters completed and student final undergraduate GPA, likelihood of obtaining a post-graduation job, and starting salary [29]. Their sample included 1,479 senior engineering students from a single institution with 12 different engineering majors. Controlling for gender, prior GPA, and major, they found that students with more undergraduate co-op experience are more likely to earn higher final GPAs, to receive offers for a full-time position post-graduation, and to have higher starting salaries. Because these previous studies have shown that there are differences in student outcomes (motivation, academic pathways, graduation rates, and career paths) by engineering major, and NACE has also documented that there are potential differences in access to co-op programs by engineering major, we examine how academic outcomes of voluntary co-op participation may also vary by engineering major [3]. We extend Schuurman et al.'s research by focusing on major-specific differences in the relationship between co-op participation and academic outcomes [29]. In this study, we ask which factors are associated with student participation in co-ops, and whether co-op participation influences likelihood of graduation in engineering and time-to-graduation. We contribute to the literature by highlighting the importance of disaggregating analyses by engineering major. An examination of the academic outcomes associated with co-op participation major-by-major will provide prospective co-op participants with more relevant information regarding the benefits and disadvantages of co-op participation by engineering major. It will also help highlight areas on which prospective employers and co-op offices may focus to enhance recruitment and participation. Thus, we examine how co-op participation, as well as the associated likelihood of graduation and time to degree, varies by engineering major [16, 17]. We use Terenzini and Reason's Model of Influences on Student Learning and Persistence to guide our study [30, 31].

2.5 Conceptual Framework

To help inform our analysis of the influence of cooperative education on student outcomes, we used Terenzini and Reason's Model of Influences on Student Learning and Persistence [30, 31]. This framework is designed to ''guide understanding of the effects of the college experience on any given educational outcome'' [32, p. 64] and consists of four main constructs: student precollege characteristics and experiences, the organizational context, the peer environment, and individual student experiences. In our study, we adapt Terenzini and Reason's model to the context of the influence of co-op participation on student persistence and time-to-graduation (Fig. 1).

We address all the main constructs in our adapted conceptual model, illustrated in Fig. 1. For student precollege characteristics and experiences, we take into account student race/ethnicity and sex in our regression models, whereas for organizational context, we address co-op program requirements and policies and employer hiring by engineering major. We address co-op GPA eligibility requirements in our model by limiting our analyses to the minimum GPA requirement of 2.60, as well as including an individual student's semester two GPA. We use semester two GPA because that is when students first become eligible to apply for co-ops, and GPA is used to determine eligibility. In our conceptual model (Fig. 1), the individual student's GPA is included under individual student experiences. Although we are unable to directly measure employer hiring in our models, we present descriptive summaries regarding co-op openings and hiring

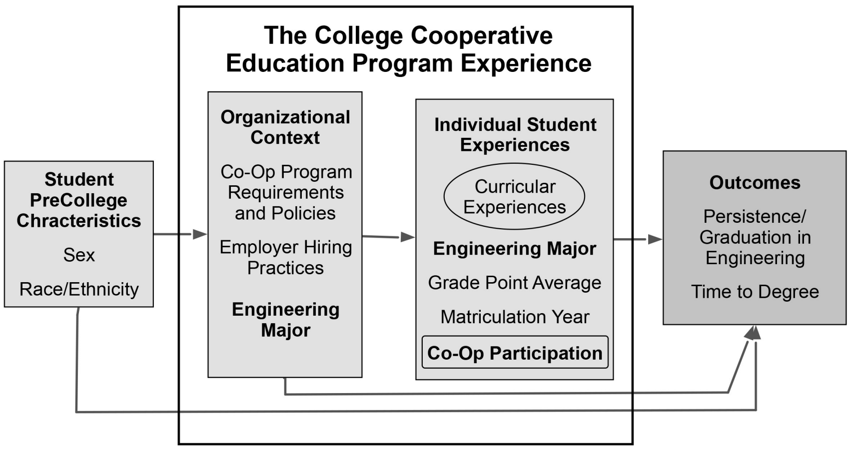

Fig. 1. Conceptual model of the influence of co-op participation on persistence and time-to-graduation (Adapted from Terenzini & Reason [2005] and Reason [2009]).

to illustrate the differences in opportunities across engineering majors. The employer data are described in more detail below and summarized in Table 1. Table 1 shows the variation in co-op opportunities by major and the variation in the number of students applying for co-op positions by major. We also provide information regarding the average compensation for co-op participation by major and number of sessions in Table 2.

In terms of the peer environment, Terenzini and Reason indicate that it "embodies the system of dominant and normative values, beliefs, attitudes, and expectations that characterize a campus's student body," and therefore perhaps may be "more easily sensed than measured" [30, p. 11]. While the different engineering majors may have distinct cultures that may play a role in the peer environment and students' relative interest in and value of co-ops, there are no direct measures for this construct [12, 13]. Finally, for individual student experiences, co-op participation is the college-level experience of our primary interest. We take into account student's engineering major, matriculation year, and GPA. For our outcomes, we examine whether co-op participation is associated with a higher likelihood of graduation in engineering, and among those who graduate, whether there are differences between co-op students and non-co-op students in time-to-graduation, by engineering major.

3. Methodology

3.1 Data and the Organizational Context

Our data come from a research-intensive academic institution in the Midwest that represents one of the largest engineering programs in the United States. We collected transcript data from the registrar and data on co-op employer hiring preferences from the institution's co-op student services office. We identified students as having participated in co-op if they have at least one co-op rotation noted on their transcript. Engineering students are ordinarily given information regarding participation in co-ops during their first semester, and recruitment events take place in the second semester. We omitted international students (1,334) from our sample because their access to co-op jobs can be different from that of domestic U.S. students – among co-op participants, only 2.5% identified as international students. To partially account for potential selection bias in participation, we also limited the sample to students who met the co-op minimum GPA eligibility requirement of 2.60 or higher in their second semester. The resulting sample includes records of 6,712 students who declared engineering as a major between 1999 and 2011. The sample includes students who were enrolled in aerospace, chemical, civil, computer & electrical, industrial, and mechanical engineering at the end of their second semester in college. In the section that follows, we provide more information regarding the organizational context for this voluntary co-op program.

3.1.1 Organizational Context: Description of Co-op Program and Placements

Co-op participation at this institution is voluntary (rather than mandatory) and is available as 3-semester or 5-semester rotations. Co-op students at this institution spend each work session with the same employer. The expectation is that there will be increasing levels of responsibility with each rotation. Co-op students are also provided a competitive salary for each work session, which increases progressively and varies by the engineering major and employer. Students interested in the 5-semester co-op typically submit applications in their first year and must have a 2.80 or higher GPA, whereas students interested in the 3-semester co-op typically apply in their second year and must have a 2.60 or higher GPA. After applications are submitted, most employers select students to participate in on-campus interviews. Placements are then based on the student's academic achievement, application, and interview (for those employers who do on-campus interviews), as well as the number of openings an employer may need to fill.

To illustrate differences in the co-op context by engineering major discussed in our conceptual model (Fig. 1), Table 1 summarizes the number of sophomores, number of student applicants, number of interviews with co-op employers, number of placements in co-ops, and percentage placed in co-ops across majors in 2015. We descriptively show the importance of disaggregating our analyses by engineering major due to the differences in the co-op application and placement context that applicants encounter based on their major. Due to limited availability of co-op employer data, we are unable to incorporate employer-related factors into our regression models. Table 1 includes information on both 3-semester and 5-semester co-op programs from the sample institution. In that year, there were 1,353 sophomores eligible for co-ops across these six majors and 463 students submitted applications to the co-op program. Co-op employers conducted a total of 852 interviews, such that a student applicant may have participated in interviews with more than one employer. A total of 258 students were placed in co-op for an overall 56% placement rate. However, when disaggregated by major, co-op placement rates vary.

Table 1 shows that mechanical engineering has the highest number of students participating in co-

Table 1. Employer Data for One Academic Year (2015)

Major	Number of Sophomores	No. of Co-op Applicants	No. of Interviews	No. of Interviews / No. of Students Applied	No. of Students Placed	Percent Placed / Applied
Aerospace	156	78	31	0.40	22	28.2%
Chemical	156	75	199	2.65	63	84.0%
Civil	117	21	56	2.67	6	28.6%
Comp & Elec	279	96	146	1.52	28	29.2%
Industrial	198	43	74	1.72	19	44.2%
Mechanical	389	150	346	2.31	120	80.0%
Total	**1,353**	**463**	**852**	**1.84**	**258**	**55.7%**

ops (120), with a placement rate of 80%. This is not surprising given that mechanical engineering has the largest enrollment of sophomores and also has the largest interest from co-op employers as measured by the number of interviews. At this institution, there is a strong tradition of co-op participation in mechanical engineering because the co-op program was started in mechanical engineering. Some of the co-op employers have been recruiting from mechanical engineering for more than 40 years. Additionally, there is a perception that mechanical engineering is a "broad" major in that the students are prepared for a wide range of engineering career trajectories. In contrast, the co-op placement rate in aerospace engineering is relatively lower at 28%. Although aerospace engineering is a popular major given the department's history of research excellence, there are relatively fewer co-op opportunities. This could be due to the overall lower number of positions available in this field, the specialized nature of aerospace engineering, and/or the level of security clearance required for some projects. Aerospace engineering students seeking co-op employment therefore have a more competitive environment for obtaining co-op positions. As a comparison, both aerospace and chemical engineering have 156 co-op eligible sophomores. About half of aerospace (78) and half of chemical (75) apply for co-op positions, but the co-op placement rate for aerospace is only 28% versus chemical engineering at 84%.

Computer and electrical engineering also has a relatively lower co-op placement rate at 29.2%, despite being a large enrollment major with 279 co-op eligible sophomores. Employers seeking computer and electrical engineers have a strong pressure to recruit qualified candidates for full-time employment. That is, the demand for qualified candidates is stronger for employers. Therefore, students have more opportunities for particularly lucrative summer internships, in addition to longer-term co-op opportunities. At this institution, computer and electrical engineering students, compared to students from other engineering majors, have more opportunities to gain engineering professional experiences through multiple pathways, including internships and co-ops. Therefore, many computer & electrical engineering students choose to pursue internships instead because they are able to graduate in four years while having conducted two or three summer internships. The lower placement rate of 29% is thus more reflective of student preferences for internships, rather than competitiveness of co-op positions as in aerospace engineering. There is also evidence that the lower co-op placement rate in mechanical engineering is driven by student preference for internships and employers' higher demand for qualified candidates in Table 2.

In addition to differences in co-op application and placement rates by engineering major, there are also differences in salary rates. Table 2 shows the average compensation for co-op participants for

Table 2. Average Compensation per Session by Major

	All Engr	Aero	Chem	Civil	Comp & Elec	Ind	Mech
Session 1	$2,533	$2,381	$2,788	$2,229	$2,467	$2,483	$2,546
Session 2	$2,755	$2,580	$3,003	$2,409	$2,694	$2,638	$2,780
Session 3	$3,000	$2,718	$3,318	$2,613	$2,967	$2,801	$2,997
Session 4	$3,158	$2,858	$3,482	$2,658	$3,109	$2,934	$3,174
Session 5	$3,436	$3,079	$3,958	$2,872	$3,313	$3,016	$3,386
Difference between Session 5 and 1	**$903**	**$698**	**$1,170**	**$643**	**$846**	**$533**	**$840**

each progressive session by major – for example, in mechanical engineering, co-op students earn about $2,467 in the first session, and on their fifth session with the same employer, their salary increases to $3,313. Their salary increases by about $846, which is relatively higher than the increase in aerospace ($698), suggesting that employers are providing more incentives to pursue and complete the co-op sequence. Similarly, chemical and mechanical engineering also have relatively high salary progressions with $1,170 and $842, respectively. Both chemical (84%) and mechanical (80%) engineering also have high co-op placement rates, suggesting higher employer demand for qualified candidates. Meanwhile, engineering majors with relatively more competitive co-op placements, such as aerospace, civil, and industrial, also have relatively lower salary progressions. As these descriptive tables show, co-op placement is complex and can vary as a function of higher student or employer demand that is unique to each major, as well as institution organizational context. Thus, we examine co-op participation and the associated academic outcomes disaggregated by engineering major.

3.1.2 Data: Descriptive Statistics

Table 3 summarizes the demographic characteristics of the sample. Whereas Section A summarizes student characteristics for the entire data sample, including both co-op and non-co-op students, Section B summarizes student characteristics among co-op students only. Of the 6,712 students in the sample, 1,011 participated in co-ops (15.1%), and 5,701 (84.9%) did not participate in co-ops. The average graduation rate in an engineering major is higher for co-op participants (95.4%) compared to the whole sample (87.3%), and the graduation rate in the same engineering major as initially declared is also higher for co-op participants (93.5%) compared to the whole sample (82.3%). Although our sample is limited to students who have a minimum of 2.60 GPA at the end of their second semester, the graduation rate of our sample is consistent with the graduation rate of all engineering students at this institution (including those who did not have at least a 2.60 GPA in their second semester). The overall graduation rate at this institution is relatively high at 87%, given that it is a selective research institution.

Across all students in the sample, the average final GPA is 3.26; however, when focusing only on co-op students, the average final GPA is higher at 3.46. This pattern of final GPAs being higher among co-op students is consistent even when disaggregated

Table 3.

A. Composition of Students (Co-Op Participants and Non-participants) by Major							
	All Engr	**Aero**	**Chem**	**Civil**	**Comp & Elec**	**Ind**	**Mech**
Female	18.7%	18.0%	33.6%	23.8%	8.6%	36.7%	14.0%
URM	6.6%	6.5%	6.0%	6.0%	7.5%	11.1%	5.5%
Asian	7.8%	6.9%	7.3%	4.2%	12.7%	7.1%	6.3%
White	85.5%	86.6%	86.7%	89.9%	79.8%	81.8%	88.2%
Co-op Participants	15.1%	12.3%	21.8%	17.2%	11.3%	12.7%	16.0%
Graduated in Engineering	87.3%	85.7%	87.0%	91.3%	83.4%	92.5%	88.6%
Graduated in Same Engineering Major	82.3%	82.4%	81.0%	86.3%	77.4%	87.9%	84.0%
Final Average GPA	3.26	3.29	3.34	3.24	3.25	3.25	3.22
Number of observations	**6,712**	**957**	**917**	**739**	**1,574**	**479**	**2,046**
B. Composition of Only Co-op Participants by Major							
	All Engr	**Aero**	**Chem**	**Civil**	**Comp & Elec**	**Ind**	**Mech**
Female	21.3%	30.5%	32.5%	22.0%	6.7%	50.8%	13.1%
URM	4.3%	4.2%	3.0%	5.5%	6.2%	4.9%	3.4%
Asian	5.0%	5.9%	2.5%	15.7%	6.7%	8.2%	6.1%
White	90.7%	89.8%	94.5%	92.9%	87.1%	86.9%	90.5%
Graduated in Engineering	95.4%	98.3%	92.0%	97.6%	94.4%	96.7%	95.7%
Graduated in Same Engineering Major	93.5%	96.6%	91.0%	96.9%	90.4%	95.1%	93.9%
Final Average GPA	3.46	3.54	3.50	3.34	3.49	3.48	3.42
Number of observations	**1,011**	**118**	**200**	**127**	**178**	**61**	**327**

by engineering major. For example, co-op students in industrial engineering have an average final GPA of 3.48 compared to a final GPA of 3.25 among all co-op eligible students in industrial engineering. Table 3A also shows that 21.8% of co-op participants are from chemical engineering, 17.2% from civil engineering, and 16.0% from mechanical engineering. This is consistent with the relatively higher co-op placement rates shown in Table 2. Focusing only on co-op participants, Table 3B shows that about half of the co-op participants in industrial engineering are women compared to 6.7% women in computer and electrical engineering and 13.1% women in mechanical engineering. Only 4.3% of co-op participants across all majors identified as a URM student, with 6.2% in computer and electrical engineering (highest) and 3.0% in chemical engineering (lowest).

Table 4 summarizes the average number of enrolled semesters to engineering degree completion by major. The first column shows the mean number of enrolled semesters to graduation (and standard deviation) for non-co-op participants, whereas the second and third columns show the mean number of enrolled semesters to graduation (and standard deviation) for 3-session and 5-session co-op participants, respectively. For reference, each academic year is composed of three semesters: Fall, Spring, and Summer. As can be expected, across all engineering majors in the sample, students who participate in 3-session and 5-session co-ops are enrolled for more semesters than students who do not participate (Table 4). For example, in aerospace, the average time-to-graduation for 5-semester co-op participants is 13.27 enrolled semesters compared to 11.71 for 3-semester co-op participants, and 9.50 enrolled semesters for non-participants. The difference in time-to-graduation between 5-semester co-op students and non-participants is about 3.77 enrolled semesters in aerospace engineering. Meanwhile, in computer and electrical engineering, the average time-to-graduation for students who participate in 5-semester co-ops is 13.69 compared to 11.25 and 9.49 among 3-semester co-op participants and non-participants, respectively. The difference in time-to-graduation between 5-semester co-op students and non-participants is about 1.77 enrolled semesters in computer and electrical engineering, which is relatively lower than that found in aerospace engineering.

3.2 Methods

This study identifies the factors associated with co-op participation and the influence of co-op participation on academic outcomes, including the likelihood of graduation in engineering and time-to-graduation. We use logit regression to identify the likelihood of co-op participation and graduation in engineering because they are both dichotomous variables. We apply ordinary least squares linear regression to estimate the influence of co-op participation on time-to-graduation since it is measured continuously in number of enrolled semesters/terms from matriculation to graduation. For each of these outcomes, we run a regression model aggregating all majors, and then a separate regression model for each engineering major in the sample: aerospace, chemical, civil, computer & electrical, industrial, and mechanical.

3.2.1 Likelihood of Participation in Co-op Program

To identify the factors associated with co-op participation, we conduct logit regression analysis using the following equation:

$$log(co\text{-}op) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \quad (1)$$

The outcome of interest, participation in co-op, is binary and is equal to 1 for participants and 0 for non-participants. The independent variables are drawn from our conceptual model (Fig. 1), and include cumulative second-semester GPA (X_1), sex (X_2), race/ethnicity (X_3), and matriculation year (X_4). Race/ethnicity includes White, Asian,

Table 4. Time-to-graduation in Engineering by Major (Number of Enrolled Semesters)

Engineering Major	Semesters-to-graduation (Non-co-op)		Semesters-to-graduation (3-session Co-op)		Semesters-to-graduation (5-session Co-op)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Aerospace	9.50	1.59	11.71	1.36	13.27	1.22
Chemical	9.47	1.71	12.36	0.67	13.56	0.81
Civil	9.32	1.43	12.07	0.91	13.47	1.15
Comp & Elec	9.49	1.61	11.25	1.26	13.69	1.07
Industrial	9.14	1.54	11.33	0.58	13.45	0.83
Mechanical	9.73	1.67	12.85	1.22	13.95	0.77

N = 5,819.

Table 5. Likelihood of Co-op Participation

	(1) All Engr	(2) Aero	(3) Chem	(4) Civil	(5) Comp & Elec	(6) Ind	(7) Mech
Marginal Effect (Std. Error)							
Semester 2 GPA	**0.145*** (0.011)**	**0.190*** (0.011)**	**0.176*** (0.033)**	**0.109*** (0.033)**	**0.121*** (0.020)**	**0.107** (0.037)**	**0.155*** (0.020)**
Female	0.012 (0.011)	**0.088*** (0.023)**	0.000 (0.028)	–0.015 (0.031)	–0.031 (0.031)	**0.063** (0.030)**	–0.016 (0.023)
URM	**–0.048** (0.016)**	0.041 (0.041)	**–0.123** (0.045)**	0.026 (0.066)	–0.026 (0.029)	–0.071 (0.037)	–0.050 (0.032)
Asian	**–0.044* (0.015)**	0.015 (0.046)	**–0.157*** (0.036)**	–0.098 (0.053)	**–0.057** (0.020)**	0.047 (0.071)	0.016 (0.036)
N	**6,712**	**957**	**917**	**739**	**1,574**	**479**	**2,046**

Note: Student matriculation year is not shown. Engineering major variables in "All Engineering" model not shown. Standard errors in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

and Underrepresented Racially Minoritized (URM; Black, Hispanic/Latino, and Native American) students. White is the reference category for the race/ethnicity variable, whereas male is the reference category for the sex variable. We conducted a regression model with the sample of students from all of the engineering majors and take into account engineering major as dummy variables in the model (X_5) (Table 5, Column 1). We also conducted six separate regression models for each of the engineering majors in the sample (Table 5, Columns 2–7).

3.2.2 Likelihood of Graduating in Engineering (and in the Same Initial Engineering Major Declared)

To estimate the influence of co-op participation on the likelihood of graduating in engineering among students who matriculate in engineering, we use logit regression analysis. The equation is as follows:

$$log(Graduation\ in\ Engr) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon \quad (2)$$

where X_1 represents co-op participation, X_2 cumulative second semester GPA, X_3 sex, X_4 race/ethnicity, X_5 matriculation year, and for the model aggregating all engineering, X_6 engineering major. Similar to equation 1 above, White and male are the reference categories for their respective variables. The outcome variable indicates whether the student graduated from the same engineering major as they initially declared in their second semester of study. Again, we aggregate across all engineering majors (Table 6, Column 1), as well as estimate this regression model separately for each engineering major (Table 6, Columns 2–7).

3.2.3 Time-To-Graduation in Engineering

We applied an ordinary least squares linear regression model to examine the effect of co-op participation on time-to-graduation, which is shown in equation 3 below:

$$Semesters\ attended = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon \quad (3)$$

Table 6. Likelihood of Graduating in Engineering in Same Initial Engineering Major Declared

	(1) All Engr	(2) Aero	(3) Chem	(4) Civil	(5) Comp & Elec	(6) Ind	(7) Mech
Marginal Effects (Std. Error)							
Co-op	**0.124*** (0.018)**	**0.216** (0.072)**	**0.115** (0.038)**	**0.211*** (0.060)**	**0.125** (0.043)**	0.094 (0.065)	**0.113*** (0.031)**
Semester 2 GPA	**0.179*** (0.012)**	**0.149*** (0.031)**	**0.201*** (0.029)**	**0.067* (0.033)**	**0.251*** (0.024)**	**0.112** (0.041)**	**0.201*** (0.022)**
Female	0.011 (0.013)	0.068 (0.035)	–0.002 (0.026)	0.039 (0.031)	–0.058 (0.035)	0.012 (0.041)	–0.028 (0.022)
URM	–0.023 (0.019)	0.000 (0.049)	0.086 (0.043)	–0.042 (0.061)	–0.007 (0.039)	–0.017 (0.050)	**–0.090** (0.038)**
Asian	**0.049** (0.015)**	0.010 (0.047)	0.077 (0.041)	0.108 (0.034)	**0.097** (0.026)**	–0.025 (0.061)	0.021 (0.030)
N	**6,712**	**957**	**917**	**739**	**1,574**	**479**	**2,046**

Note: Student matriculation year is not shown. Major control variables in "All Engineering" model not shown.
Standard errors in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

The indicator variables are the same as those used in equation 2; however, for co-op participation, we distinguish between 3-semester and 5-semester co-op participation and use "no participation" as the reference category. Note that Fall, Spring, and Summer each count as a semester, such that an academic year is composed of three semesters in our data. The outcome variable is the total number of semesters the student was enrolled from matriculation through graduation. The variable measures the number of semesters that the student was enrolled, rather than time elapsed. At this institution, co-op students are officially enrolled during semesters that they are off-campus participating in co-ops. During these work periods, co-op students are still enrolled at the institution, although not necessarily taking any on-campus courses. Again, we conduct our analyses for all engineering majors aggregated, as well as separately for the six engineering majors.

4. Results

In this section, we present our results by outcome of interest: (1) likelihood of co-op participation, (2) likelihood of graduating in engineering (in the same major as initially declared), and (3) time-to-graduation in engineering.

4.1 Likelihood of Participation in Co-op Program

The results from our logit regression analyses are reported using marginal effects in Table 5. The first column reports the results for all the engineering majors aggregated. Cumulative GPA at semester two and race/ethnicity are associated with co-op participation in this aggregated engineering major model (Table 5, Column 1). Students with higher cumulative second-semester GPAs are more likely to participate in co-ops. However, Asian and URM students are less likely to participate than their White counterparts.

Higher academic achievement as measured by the cumulative second-semester GPA is associated with a greater likelihood of participating in co-ops across each of the engineering majors (Table 5, Columns 2–7). For example, in industrial engineering, a one-point increase in GPA is associated with a 10.7 percentage point increase in the likelihood of participating in co-ops, whereas in aerospace engineering, a one-point increase in GPA is associated with a 19.0 percentage point increase in the likelihood of co-op participation.

Whereas cumulative GPA has a positive relationship with likelihood of co-op participation across the different majors, the relationship between demographic factors (sex and race/ethnicity) and co-op participation varies by engineering major. When analyses are disaggregated by engineering major, we find that there is no difference in the likelihood of co-op participation between men and women in chemical, civil, computer and electrical, or mechanical engineering. Meanwhile, women are more likely than men to participate in co-ops in aerospace and industrial engineering by 8.8 and 6.3 percentage points, respectively. URM (Black, Hispanic/Latino, and Native American) students majoring in chemical engineering are less likely than their counterparts to participate in co-ops by 12.3 percentage points. However, URM students are just as likely to participate in co-ops as White students in the other engineering majors, including aerospace, civil, computer and electrical engineering, industrial, and mechanical engineering. Compared to their White counterparts, Asian students are also less likely to participate in co-ops among those majoring in computer & electrical and chemical engineering by 5.7 and 15.7 percentage points, respectively.

4.2 Likelihood of Graduating in Engineering (and in the same Initial Engineering Major Declared)

The results regarding the relationship between co-op participation and likelihood of graduating in engineering are reported in Table 6. Based on the first column, which aggregates all engineering majors, co-op participation, second-semester GPA, and race/ethnicity are associated with the likelihood of graduating in engineering. Holding second-semester GPA, sex, race/ethnicity, engineering major, and matriculation year constant, co-op participation is associated with an increase of 12.4 percentage points in the likelihood of graduation among engineering students eligible for co-op participation. Moreover, with every point increase in second-semester GPA, the likelihood of graduation increases by 17.9 percentage points. Although the likelihood of graduation is not significantly different between White and URM students, Asian students are more likely to graduate from any engineering major by 4.9 percentage points compared to White engineering students. However, when disaggregated by engineering major, we see that this positive relationship is found only in computer & electrical engineering by 9.7 percentage points (Table 6, Column 5).

The relationship between co-op participation and graduation in the same engineering major initially declared varies when disaggregated by engineering major. In all majors except industrial engineering, co-op participation is associated with higher graduation probabilities. In aerospace engineering, co-op participation is associated with an increase of 21.6 percentage points in the likelihood of graduating in engineering. Meanwhile, co-op participation

Table 7. OLS Regression on Number of Semesters to Engineering Graduation

	(1) All Engr	(2) Aero	(3) Chem	(4) Civil	(5) Comp & Elec	(6) Ind	(7) Mech
Regression Coefficient (Std. Error)							
3-session Co-op	**2.73*** (0.17)**	**2.39*** (0.37)**	**3.13*** (0.47)**	**2.72*** (0.38)**	**2.24*** (0.51)**	**2.36*** (0.86)**	**3.02*** (0.31)**
5-session Co-op	**4.29*** (0.06)**	**4.00*** (0.17)**	**4.17*** (0.14)**	**4.21*** (0.15)**	**4.30*** (0.15)**	**4.38*** (0.22)**	**4.40*** (0.10)**
Semester 2 GPA	**–0.82*** (0.05)**	**–0.84*** (0.13)**	**–0.73*** (0.13)**	**–0.57*** (0.14)**	**–0.89*** (0.12)**	**–0.62*** (0.18)**	**–0.92*** (0.09)**
Female	–0.01 (0.05)	0.19 (0.14)	0.06 (0.11)	–0.14 (0.12)	**–0.32* (0.17)**	–0.07 (0.15)	0.14 (0.10)
URM	**0.53*** (0.08)**	**0.54** (0.21)**	**0.54** (0.22)**	**0.55** (0.23)**	**0.60*** (0.18)**	–0.29 (0.23)	**0.82*** (0.17)**
Asian	**0.14** (0.07)**	–0.17 (0.21)	0.12 (0.20)	0.42 (0.26)	0.15 (0.14)	–0.14 (0.28)	**0.30** (0.15)**
Intercept	**12.12*** (0.18)**	**12.22*** (0.44)**	**11.91*** (0.46)**	**11.18*** (0.44)**	**12.53*** (0.40)**	**11.23*** (0.57)**	**12.68*** (0.31)**
N	**5,819**	**820**	**798**	**675**	**1,312**	**443**	**1,812**
R^2	**0.49**	**0.43**	**0.57**	**0.57**	**0.41**	**0.50**	**0.53**

Notes: Sample includes students who graduated in engineering (both co-op and non-co-op participants who had at least a 2.6 GPA in their second semester). Student matriculation year is not shown. Major control variables in "All Engineering" model not shown. *** p < 0.001, ** p < 0.01, * p < 0.05.

in chemical engineering is associated with an increase of 11.5 percentage points in the likelihood of graduating in engineering in the same initially declared major. Again, second-semester GPA is positively associated with graduation probabilities for students in each major. With every point increase in cumulative semester-two GPA, the likelihood of graduation among students majoring in aerospace, chemical, civil computer and electrical, industrial, and mechanical engineering increases by 14.9, 20.1, 6.7, 25.1, 11.2, and 20.1 percentage points, respectively.

4.3 Time-To-Graduation in Engineering

As can be expected, our regression results (Table 7) confirm the summary statistics reported in Table 4 that co-op participation lengthens time-to-graduation. On average, co-op participation lengthens the number of enrolled semesters by 2.73 among 3-session co-op participants versus non-co-op participants, and by 4.29 enrolled semesters among 5-session co-op participants versus non-co-op participants across all engineering majors (Table 7, Column 1). Consistently, co-op participation in both 3-session and 5-session co-ops is associated with increased number of enrolled semesters in each of the engineering majors (Table 7, Columns 2–7). Taking previous academic achievement, race/ethnicity, sex, engineering major, and matriculation year into account, 3-session co-op participation increases time-to-graduation by 3.13 enrolled semesters in chemical engineering and by 3.02 enrolled semesters in mechanical engineering (roughly increasing time-to-graduation by an academic year). At the other end of the spectrum, 3-session co-op participation increases number of semesters among computer & electrical engineering students by about 2.24 enrolled semesters. Participation in 5-session co-op increases time-to-graduation on average by 4.40 enrolled semesters in mechanical engineering, by 4.38 enrolled semesters in industrial engineering, and by 4.00 enrolled semesters in aerospace engineering compared to non-participants. These differences in the additional time-to-graduation by engineering major are particularly important for students who are deciding whether to participate in co-ops based on the potential added length to graduation.

5. Discussion

Drawing from our conceptual model (Fig. 1), which is adapted from Terenzini and Reason's Model of Influences on Student Learning and Persistence [30, 31], we examined the influence of student precollege characteristics, organizational context, and individual student experiences and curricular experiences on students' likelihood of participating in co-ops, likelihood of graduation in the initially declared engineering major, and time-to-graduation. We make a case for disaggregating analyses by engineering major in engineering education research because organizational context matters in determining student participation in academic interventions and the associated outcomes. We include models that aggregate all engineering majors to show that aggregated results can sometimes conceal important differences across groups and contexts.

We showed descriptively that access to co-ops through employer hiring practices, as well as position availability due to the number of applications, varies by engineering major (Table 1). Importantly, we showed that participation in co-ops varies by sex and race/ethnicity across engineering majors (Tables 3 and 5). Highlighting patterns in co-op participation by demographic factors has important implications for diversity in the engineering workforce. Since many co-op participants are offered full-time positions at their co-op companies upon graduation [3], diversifying co-op participation at the undergraduate level may be a pathway to increasing diversity in professional engineering practice. Although our study shows important patterns in co-op participation across engineering majors, our study does not address the mechanisms motivating these patterns. Women's greater likelihood to participate in co-ops than men in aerospace engineering should be examined further. Compared to other engineering majors, women comprise a smaller percentage of the graduates in aerospace engineering [33], such that employers may perhaps be making a greater effort to hire women in this field to participate in co-op opportunities. After all, greater diversity in the workforce is associated with higher levels of innovation [34]. It is also possible that women in aerospace engineering may be more motivated to pursue and obtain co-op opportunities.

Our findings also showed that URM and Asian students are less likely to participate in co-ops than their White peers in the model when all engineering majors are aggregated (Table 5 Column 1); however, when the models are conducted separately by engineering major, this pattern holds only in chemical engineering (Table 5, Column 3). Ramirez et al. found that students choose not to participate in co-ops because of the increased time-to-graduation degree, concerns over scheduling courses, the possibility of losing connections with peers, and/or other potential commitments and opportunities available on campus [9]. The URM and Asian students in chemical engineering may be more likely to find these reasons to be important, to have other commitments on campus, and/or to participate in other work opportunities, such as internships. Although our data set does not provide insights as to why URM and Asian students in chemical engineering may be less likely to participate in co-ops compared to their counterparts, it highlights an important pattern that warrants further investigation.

Cumulative second-semester GPA was associated with likelihood of co-op participation across all of the models (aggregated and disaggregated by engineering major). Although we limited our sample to those who met the minimum GPA eligibility requirement of 2.60, the results show that higher GPAs are associated with co-op participation, suggesting that employers may be more likely to hire applicants with higher GPAs – some co-op employers use an internal minimum GPA of 3.0. That is, while students are eligible to apply for co-ops with a 2.60 GPA, some employers consider or interview only applicants with a minimum of 3.0 GPA. It is also possible that students who have higher GPAs may be more likely to pursue co-op opportunities or may perform better on the interview portion of the co-op application process. While we can show the relationship between academic achievement and co-op participation, our data do not shed light on the mechanisms for why or how students with higher GPAs are more likely to participate in co-ops.

Our conceptual model (Fig. 1) proposes that students' individual and curricular experiences influence their academic outcomes, and we focused primarily on co-op participation and engineering major as factors. We found that co-op participation has a significant positive relationship on the likelihood of graduating in the same initially declared major across all engineering majors, except in industrial engineering. This may be the case in industrial engineering because compared to the other engineering majors, industrial engineering has the highest overall graduation rate at 87.9% (Table 3). Although not directly measured here, differences in likelihood of graduation by major could also be attributed to differences in students' motivation for choosing their respective majors and career intentions [27, 28]. It is possible that co-op participation may boost the likelihood of graduation through mechanisms, such as stronger motivations and connections with professional practice, as well as co-op employers' ability to recruit students most likely to graduate.

While co-op participation appears to be positively associated with likelihood of graduation, co-op students, as can be expected, tend to have longer average time-to-graduation than non-participants. However, the extended time generally matches the duration that students are actually on co-op appointments. While Blair et al. found that co-op students took, on average, an additional 2.0 semesters (7.0 months) longer to graduate than non-co-op participants [7], here we find that 3-session co-op participants take about 2.73 enrolled semesters longer and 5-session co-op participants take about 4.29 enrolled semesters longer than non-participants. However, we are also able to show the variation in the number of enrolled semesters that co-op participation increases time-to-graduation by engineering major. For example, Table 7 shows that 3-session co-op participation extends time-to-graduation by 3.02 enrolled semesters in mechanical versus only 2.39 enrolled semesters in aerospace engineering. The differences in additional semesters by major could be due to the availability of required courses (i.e., how long a student may have to wait before the next offering of a required course), the diversity of pathways through the curriculum, and/or the co-curricular activities that non-co-op participants may be engaged in, such as travel abroad or internships.

For students who may be reluctant to pursue co-op opportunities because of concerns about extending their own time-to-graduation, Table 4 also provides major-specific information for this institution regarding the average number of enrolled semesters that co-op participation may add to degree completion. Therefore, disaggregating analyses by engineering major provides students and other stakeholders, such as potential employers, with possibly more tailored information. As shown in our adapted conceptual model, student precollege characteristics, organizational context, and individual student experiences and curricular experiences all contribute to the likelihood of persistence and other academic outcomes [30, 31]. Our findings that there are differences in outcomes by engineering major illustrate that context matters and that engineering majors should be considered in engineering education research when feasible and relevant. Academic interventions, such as co-op programs, can have varying effects depending on the student's engineering major, and aggregating all engineering majors may mask these important differences.

5.1 Study Limitations

While our findings illustrate the importance of disaggregating engineering majors to show patterns in co-op participation and the associated academic outcomes, there are several limitations associated with the study. Our estimates are not causal; rather, they show the relationship between individual-level characteristics and academic experiences with the likelihood of graduation and time-to-graduation in the context of specific engineering majors. There is selection bias associated with co-op participation, which we partially address by limiting the sample to students who have grade point averages that meet the eligibility requirements. However, the observable variables available do not fully capture all the factors that may play a role in co-op participation and subsequent academic outcomes. We include relevant variables that were available from the data set, but there are other factors that potentially play a role in co-op participation and student academic outcomes, such as social, cultural, and economic factors, as well as individual student factors, such as career intentions, family background, parental education, and socioeconomic status.

We use secondary data, relying on data collected and maintained by the registrar and the co-op student services office at a single institution in the United States. However, our sample institution consistently ranks among the top producers of engineering graduates in the nation, and our sample composition is relatively comparable to national averages on engineering student populations in regard to the proportion of female engineering students. Regarding race and ethnicity, our sample has a higher proportion of White students compared to the national average in engineering [33]. Therefore, the relative levels of participation of women, URM, and Asian students at this institution may not necessarily be representative of other research intensive institutions.

6. Conclusions

We examined the factors that influence student co-op participation, as well as the academic outcomes measured as likelihood of graduation in engineering and time to degree, disaggregated by engineering major. In so doing, we provide major-specific information regarding participation and outcomes of co-ops that could be applied by stakeholders in helping design and implement voluntary co-op programs. Our data include administrative and transcript data from a research-intensive institution in the Midwest with a voluntary co-op program. We analyzed data from 6,712 students who were enrolled at this institution between 1999 and 2011 using logit and ordinary least squares regression. Our findings may potentially be useful to co-op administrators, co-op employers, and other stakeholders toward further improving or developing recruitment strategies for diverse students. For example, co-op employers can apply our findings toward evaluating their eligibility requirements and selection processes. Our findings can also be informative for students determining what the potential academic returns may be to voluntary co-op participation and how the returns might vary across engineering majors using data from this research institution. Additionally, this study advances the literature by showing important major-specific patterns associated with co-op participation and academic outcomes, as well as by highlighting the importance of disaggregating majors in examining the effects of co-curricular and academic interventions.

Our findings illustrate the importance of considering potential variation across engineering majors for engineering education researchers. We make a case for examining the relationship between co-op participation and academic outcomes by engineering major, rather than all engineering majors aggregated. Doing so helps uncover insights regarding the relative importance of co-ops in the academic outcomes of engineering students by engineering major. Our conceptual model (Fig. 1) supports the need to examine student academic outcomes from multiple perspectives – individual student characteristics, organizational context, and individual student experiences and curricular experiences. Consistent with our conceptual model, we found that student academic outcomes, likelihood of graduation, and time-to-graduation vary by student demographic characteristics (sex and race/ethnicity), organizational context (engineering major), curricular experiences (GPA), and individual student experiences (co-op participation). The value of disaggregating engineering majors in empirical analyses is not limited to the study of co-op programs, but can also be extended to other co-curricular programs and educational interventions in engineering education.

Our research findings are consistent with previous literature indicating that co-op participation is associated with higher graduation probability, but also that it is associated with a longer time-to-graduation. However, our findings also highlight differences across engineering majors. For example, while co-ops lengthen time-to-graduation across all engineering majors, it may be more so in chemical and mechanical engineering. In terms of engagement, there are differences in the demographic composition of co-op participants by engineering major. Our results contribute to the engineering education literature by showing important major-specific patterns associated with co-op participation and academic outcomes. Future work could further investigate the reasons and the motivations, behaviors, policies, and factors that contribute to these patterns. Incorporating social, cultural, and economic variables into the analysis could provide additional context to analyze factors influencing outcomes of interest. Additional studies focusing on each major as a case study could also provide more comprehensive understanding of how individual demographic characteristics, individual experiences, and organizational context contribute to variation in student outcomes. Furthermore, exploration of employer factors in co-op participation could provide insight into policies for broadening participation.

Regarding co-ops at our sample institution, the benefit of co-op participation on the likelihood of graduation varies across engineering majors, and illustrating these differences provides critical information for stakeholders. Disaggregating by engineering major shows important patterns in the relative levels of participation across subgroups of students by race/ethnicity and gender, highlighting relevant patterns for employers interested in diversifying their workforce. Academic program administrators, student services, co-op employers, and faculty can potentially use our research findings to help inform strategies to recruit more diverse co-op participants and/or to design co-curricular programs to help increase student retention and/or reduce time-to-graduation. Students can also apply the research findings to make more informed choices regarding the advantages and disadvantages of co-op participation. Research findings suggest that engineering undergraduate students considering participation in voluntary co-ops should refer to co-op information specific to their engineering major. Our findings make a case for examining the impact of programs and interventions by disaggregating engineering majors and considering organizational context.

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