Longitudinal Analysis of Co-Curricular Involvement Among Engineering Undergraduates: Exploring Timing, Type, and Self-Reported Skills Development

Bahar Memarian
The State University of New York at Buffalo

Andrew Olewnik
The State University of New York at Buffalo

The purpose of this study is to explore the self-reported professional competencies gained by engineering students involved at different rates and types of co/extra-curricular activities (CECAs) between their grade 12 and junior years of undergraduate engineering education. The contribution of this work is in using longitudinal data to understand how student engagement and learning outcomes might evolve to inform potential co-curricular programming changes. We analyzed data from an annual professional development survey from 970 students from 2016-2019. Findings show that higher engagement may not necessarily lead to higher skill acquisition for all students per unit of time, particularly in engineering-focused facets of professional skills. Co-curricular spaces are prone to be dominated by certain demographic profiles, and students are likely to engage in nontechnical work and clubs, as compared to co-curricular projects and research experiences. We conclude that future work should attempt to specify the "goldilocks" level of involvement, understand barriers to participation, and robustly characterize the nature of learning and students' recognition of their learning through CECAs.

Keywords: co-curricular, engineering education, experiential learning, involvement, professional development

INTRODUCTION

The purpose of this study is to explore the characteristics of a student cohort who engaged at different rates in co-curricular or extracurricular activities over their pre-collegiate (i.e., grade 12) through the junior year (i.e., year 3) of undergraduate engineering education. The findings are intended to support policy and pedagogy related to co-curricular programming. Co-curricular activities typically reside outside of but complement the curriculum (e.g., undergraduate research, internships, engineering student clubs). We differentiate these from extra-curricular activities, which may be school-based but are not related to the curriculum (e.g., intramural sports, and community organizations) (Rutter & Mintz, 2016). As this study considers data related to both co- and extra-curricular activities, the acronym CECA is used throughout.

To gain a better understanding of the CECA participation climate, we examined survey data with the following research questions:

- *RQ1: At what predominant (exhibited by >10% population) academic levels do CECA engagements occur and what skills are self-reported to be developed?*
- *RQ2: What are predominant (exhibited by >10% population) selections of CECAs and what skills are self-reported to be developed?*

These research questions are motivated by the need to understand more about student participation in CECA activities over their undergraduate careers and the potential impact of that involvement. This study fits within the body of research that seeks to characterize the impact of such experiences on student development (Burt et al., 2011; Doig, 2019; Evans, 2013; Knight & Novoselich, 2017; Krause et al., 2015; Lutz & Marie, 2021; Ohland et al., 2008; Ro & Knight, 2016). The literature suggests that higher student engagement in CECAs may lead to more professional skill development and student identity formation as future engineers (Bergen-Cico & Viscomi, 2012; Burt et al., 2011; Elias & Drea, 2013). Principal learning theories related to student involvement, inclusive of CECAs, pose that student background, environment, efforts, and values shape the nature of involvement, and suggest that the sum (and quality) of student engagements yields learning (Astin, 1999; Tinto, 1987). Comparing student groups who engaged CECAs at different rates, times, and types, and their self-reported learning can help us understand whether more frequent engagement is a viable approach for all and if not, what additional factors need to be considered.

This study is made possible by analyzing longitudinal data from a large public, R1 institution in the Northeast United States collected from 2016 to 2019 wherein students self-reported their CECA engagement annually. Data included self-reported professional skills developed/engaged as well as student demographic information tracked by the institution. We compared the characteristics of student groups who had different total CECA engagements during that time frame, namely 1 engagement (n=344), 2-3 (n=314), 4-5 (n=165), and 6-11 (n=135).

The literature review in the next section considers the body of work on co-curricular and professional development research and learning theories in engineering education, and higher education more generally. The methods section outlines our analytical approach, which is situated in a grounded theory lens and applies an exploratory analysis of a Professional Development Survey (PDS) and institutional data. The results section shares the summary of dominant trends between groups of students who engage at different rates in CECAs. Findings show that higher engagement may not necessarily lead to higher skill acquisition for all students when considered on a per-engagement basis, particularly in engineering-focused facets of professional skills, and that factors both internal and external to the student may confound students' engagement and uptake. We last consider the importance and implications of such findings on engineering education's teaching and learning efforts in the discussion section.

LITERATURE REVIEW

In engineering education literature, Astin and Tinto's theories have been used as conceptual frameworks to guide the CECAs of students (Finelli et al., 2012; Henderson, 2017; Millunchick & Zhou, 2020b, 2020a). The theories pose that the learning and demographic backgrounds of students, their efforts during their studies, future aspirations, as well as the environment they work within all shape students' learning experiences (Astin, 1999; Tinto, 1987).

Astin's theory of involvement poses that learning and personal development are proportional to students' level of engagement (Astin, 1999). Further, that experience is influenced by a combination of students' inputs such as previous learning and demographic backgrounds, environments such as the type of CECAs they engage in, and outputs such as knowledge and skills gained values, and aspirations developed (Bergen-Cico & Viscomi, 2012; Elias & Drea, 2013).

Tinto's model of institutional departure recommends that the series of experiences the student accumulates in their studies and both academic and social (e.g., CECA) environments come to determine the chances of student integration and belonging, and ultimately impact persistence within the institution (Tinto, 1975). The authors posit that engagement in CECAs can make a significant contribution to student learning and development. Yet it is unclear how students engage in CECAs and the extent to which that involvement yields an accumulation of professionally relevant skills.

Engagement in CECAs can lead to a holistic educational experience and the acquisition of multiple professional competencies. The development of such competencies has been shown to play an influential role in student achievement in the engineering profession (Finelli et al., 2012; Shuman et al., 2005).

Professional competencies comprise a diverse array of skills, behaviors, or attributes in engineering education (Passow & Passow, 2017), (Dall'Alba & Sandberg, 2006). The ability to "devise process" to solve problems and coordinate a variety of technical and non-technical skills is critical to success in practice (Passow & Passow, 2017).

Public and/or private higher education agencies have created a diverse set of criteria across different institutions or countries to advise faculty and students on learning objectives for professional preparation. The international multi-disciplinary Definition and Selection of Competencies (DeSeCo) project, for example, has developed a framework for understanding competencies (OECD, 2005). On a national scale, an example is the Employability Skills 2000+ which lists the critical skills that are sought after in the Canadian workplace (Conference Board of Canada, 2000). Similarly, ABET has provided criterion on the characteristics of professional skills and require the formation of a set of abilities in students (ABET, 2021). Examples include but are not limited to functioning in multi-disciplinary teams, acknowledging ethical responsibility, identifying contemporary issues, lifelong learning, and effective communication (ABET, 2021; Shuman et al., 2005). Administrators (e.g., faculty or industry supervisors) may however interpret and account for professional skills in different ways. There are, for instance, diverging views on whether professional skills should be considered as a set of generic skills embedded in practice with or without engineering content-specific skills (Male, 2010; Shuman et al., 2005).

Because curricular spaces primarily focus on theoretical concepts, there are limited authentic opportunities for students to develop their professional skills (Adams & Felder, 2008). To compensate for this, CECAs (e.g., on-campus/off-campus and paid/volunteer social workspaces) are encouraged and supported by universities to enable students' embedded practice of professional skills as part of a holistic educational experience. CECAs have been defined in different terms in the literature (Bartkus et al., 2012). Our interpretation is that CECAs encompass a set of learning experiences and activities supported by the institution (e.g., undergraduate research, student engineering clubs) or external bodies (e.g., off-campus technical and non-technical work experiences, community service) that students engage with outside the engineering classrooms and that is separate from students' (required) curricular commitments. Together, CECAs and curricular activities can provide a holistic development of a well-rounded learner in their chosen program of study.

Research done on experiential engagement asserts that engagement in CECAs can help student persistence (Burt et al., 2011; Freeman, K., Ellis, M., Parham-Mocello, J., & Walker, 2020; Jamison, C. S. E., Huang-Saad, A., Daly, S. R., & Lattuca, 2020; Kuh, 2008), though understanding retention/persistence is complex (Reason, 2009). Engagement in CECAs has also been shown to support student professional development that goes beyond the mere knowledge of theory and is more representative of real-world practice (Foubert & Urbanski, 2006; Turrentine et al., 2012). Such practice is embedded in student identity and engagement with society. Participation in CECAs can instill a sense of self-efficacy, motivation, satisfaction, and social awareness, and strengthen networking abilities in students (Stirling & Kerr, 2015). There is also evidence that student engagement in CECAs supported by the institution can increase student chances of employability and success post-graduation (Coates, 2015; Muldoon, 2009). Much of the dominant models of professional development in education literature signify that students, regardless of their diverse backgrounds, become skilled professionals through gaining more practical experience in authentic settings (Dall'Alba & Sandberg, 2006). Similar findings are reported in engineering education literature indicating that students' frequent engagement in CECAs, especially ones closely tied to the engineering discipline, are likely to advance students' professional skills and identity as future engineers (Bergen-Cico & Viscomi, 2012; Burt et al., 2011; Elias & Drea, 2013).

Despite evidence that CECA participation is valuable, it is still unclear how student involvement in CECAs evolves to impact professional development (Heller et al., 2010; Smith et al., 2005). Further, there is limited insight into student representation in CECAs (Chaudhury et al., 2019; Lee & Matusovich, 2016). Specifically, little is known about the intensity of student involvement and factors that lead to greater professional development (Burt et al., 2011; Millunchick & Zhou, 2020a). We draw from Astin and Tinto's prominent theories to acknowledge students come to experience and hence build knowledge by navigating between both curricular and co-curricular spaces. Professional skills and learning that remain with students are proportional to the sum of engagements in curricular and co-curricular experiences. We follow these theories to explore the extent to which students report an accumulation of professional skills as they engage in CECAs at different rates.

METHODS

We explored trends related to the type and timing of CECA engagements and self-reported professional learning outcomes of student groups who had engaged at different rates in CECAs between 2016 to 2019. We used the grounded theory as our methodological framework due to a lack of insight from the literature on how involvement in different CECAs influences students' efforts and outcomes. Grounded theory is not driven by a theoretical framework but instead attempts to find insight and trends around a research question by analyzing the data (Conrad, 1982).

Data Collection

We analyzed institutional records of students considering multiple sources. These included the annual Professional Development Survey (PDS) as well as data tracked by the institution (i.e., admissions, demographics, etc.). Through the PDS survey, all engineering undergraduate students are asked to self-report and reflect on CECAs in which they participated during the previous year (i.e., students who completed the survey in fall 2020 would be reporting about activities that occurred between fall 2019 and summer 2020). Students are asked to report on experiences that fall under a variety of CECA categories. We considered the following categories in our analysis:

- Technical Work Experience: Off-campus internship or co-op industry experiences, which may or may not earn academic credit,
- Non-Technical Work Experience: Off-campus work experiences that are not deemed as engineering/technical/computer science-related work (e.g., working at a grocery store),
- Research Experience: On-campus laboratory and/or research work conducted with a supervising faculty member,
- Student Clubs/Organizations: Student Clubs, some of which pursue technical projects as part of student competitions or provide networking and professional development opportunities (e.g., ASCE steel bridge competition, SAE clean snowmobile, Women in Science and Engineering),
- Makerspace/Engineering project micro-credential: On-campus co-curricular activities that occur in the engineering maker spaces (e.g., workshops, personal projects) or as resume-building projects sourced from industry, community groups, or students through which students can earn a micro-credential. The specific names of these programs have been redacted to ensure the anonymity of the institution.
- Outreach or Community Service: On- or off-campus engagement in social work through various community groups and organizations.

By responding to the annual PDS survey, students self-reported data for each engagement that included the:

- Type of CECA,
- Types of professional competencies they used/developed/improved form a list of 9: 1) critical thinking/problem solving, 2) engineering design, including use of relevant codes/standards, 3) use of appropriate computer technology, 4) use of engineering tools, 5) oral/written

communication, 6) teamwork/collaboration, 7) leadership, 8) professionalism/work ethic/integrity, and 9) project/time management.

Additional data about the students provided by the institution included:

- Gender: Man or Woman,
- Race/Ethnicity: White, Asian, Black or African American, International/Non-Resident Alien, Hispanic/Latino, Unknown, Two or more races, American Indian or Alaska Native

Data Selection Criteria

The data reflect a cohort of students who were first-year students in 2016 (reporting on their grade 12 experiences from 2015-16), sophomores in 2017 (reporting on their first-year experiences in 2016-17), juniors in 2018 (reporting on their second-year experiences in 2017-18), and seniors in 2019 (reporting on their third-year experiences in 2016-17). Given the survey timing, the PDS does not provide information about the senior-year experiences of undergraduates. We intentionally restricted each year to one academic level to explore a cohort of students who were able to progress through their studies without a pause. In addition, our data set included the one-year participation of students who completed first-year to junior levels over a period longer than three years. This means that from the data selected, some students progressed at a common/traditional academic trajectory (i.e., one year per grade level) and continued participating in CECAs, and some other students either discontinued participating in CECAs or were unable to maintain a traditional pace in their academic trajectory. The primary focus, however, was on the students who can spend a year per academic level and start at the same academic level each year.

Data Processing and Analysis

We summarized and compared the background and self-reported learning outcomes of students who engaged at different rates in descriptive means. All the data processing and analysis were done using MATLAB. Data grouping was done to differentiate between engagements in a four-category scale (comparatively designated lowest, low, high, and highest participation) and ensure that at least 100 members are present in each group, resulting in the following engagement classification: 1 engagement (n=343), 2-3 (n=314), 4-5 (n=165), and 6-11 (n=135). These represent the total number of engagements reported over the four years. Thirteen students reported participating 12-21 times. However, we considered them as outliers of the population and were interested to focus on dominant participation groups.

For any student who engaged more than once, their survey participation responses were grouped chronologically and the sum of professional learning outcomes across all CECAs engaged was used for analysis. This follows the ideas by Astin and Tinto (Astin, 1999; Tinto, 1987) that pose students' learning is yielded from the sum of experiences in which they participate. Our data processing comprised the following steps:

1. Combined all student entries for one or multiple participations from 2016 to 2019 (unaggregated n = 12938, aggregated by user id n = 4310),
2. Extracted data for those who were grade 12 students in 2016, a first year in 2017, sophomores in 2018, or juniors in 2019 and who had complete responses to the "PDS" and institutional data (n = 3038),
3. Aggregated student data for those who participated more than once to have a chronological record of their engagements over time-based on a deidentified unique ID and created a data file where each entry pertains to a unique student (n = 970),
4. Found the sum of each professional skill (out of a list of 9) for each of the multiple-time participants,
5. Extracted data from those students who had demographics data from the institution and removed data from students who partially filled in the survey (n = 957),
6. Separated student data into groups based on their total engagements: 1 (n=343), 2-3 (n=314), 4-5 (n=165), and 6-11 (n=135), and
7. Compared predominant patterns of data (exhibited by >10% of each group) descriptively between the engagement groups.

Throughout this article, the terms engagement, CECA, and engagement groups refer to the total number of co-curricular participation (which may have been of the same or different types) an individual student completed between 2016 (grade 12) through 2019 (junior year). The descriptive analysis considers the predominant (exhibited by >10% of each group) summaries of time and type of engagement along with the sum of skills self-reported to be developed/engaged. The 10% cutoff emerged after exploring the data set and determining that trends below 10% often become unique to individuals and not representative of a group of students (i.e., exhibited by roughly n=34, 21, 16, and 13 or more individuals in the 1, 2-3, 4-5, and 6-11 engagement groups, respectively).

RESULTS

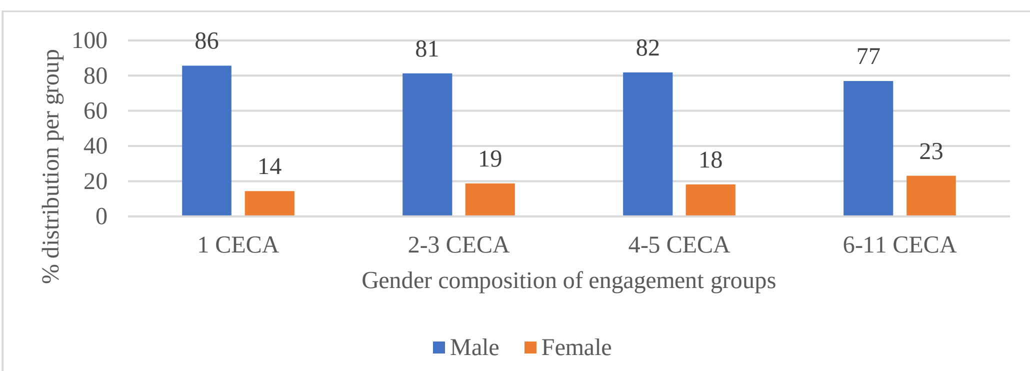
We first summarize the demographics of engagement groups and proceed with comparing the time and type selection (RQ1) and self-reported skills developed (RQ2) across groups.

Demographic Summary of Engagement Groups

Figure 1 summarizes participation rates by gender for the subset of the population studied. For reference, the total engineering undergraduate population from 2016-2019 as reported by the institution was 17% Female and 83% Male. Overall, a gender composition difference (more men than women) was consistently seen in all engagement groups. However, the percentage of female participants increased as the number of CECA engagements increased (from 14% to 23%). Conversely, the male sample percentage slightly decreased as the engagements increased (from 86% to 77%).

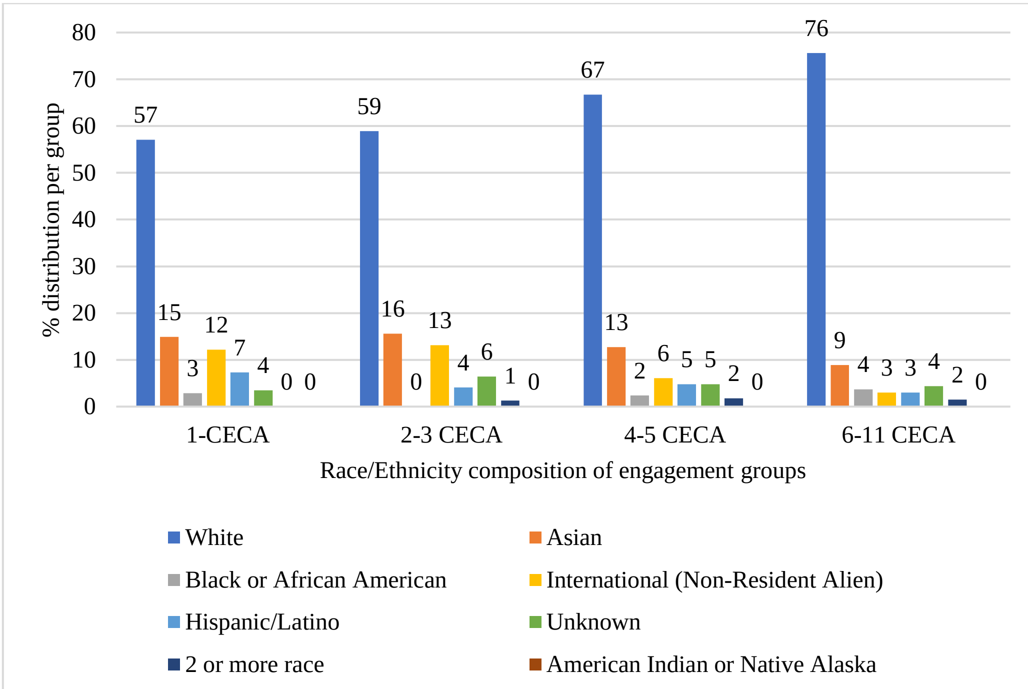
Figure 2 summarizes participation rates by race/ethnicity for the subset of the population studied. For reference, the total engineering undergraduate population between 2016-2019 was comprised of 50% White, 18% Asian, 5% Black or African American, 11% International (Non-Resident Alien), 7% Hispanic/Latino, 6% Unknown, 2% 2 or more races, 0% American Indian or Alaska Native. The race/ethnicity distribution of students who engaged once seems to be different from those who participated 6-11 times. The one-time participants were 57% white, 14% Asian, 12% International, 7% Hispanic/Latino, 4% Unknown, and 3% Black. The race/ethnicity of 6–11-time participants was, on the other hand, 76% white, with the remaining race/ethnic groups representing less than 10% of the population.

FIGURE 1
PERCENT DISTRIBUTION OF GENDER ACROSS ENGAGEMENT GROUPS*



***The total undergraduate population between 2016-2019 comprised 17% female and 83% male

FIGURE 2
PERCENT DISTIRUBTION OF RACE/ETHNICITY ACROSS ENGAGEMENT GROUPS*



***Some students had missing demographic data, hence why the sum in some groups is not 100. The total population between 2016-2019 was comprised of 50% White, 18% Asian, 5% Black or African American, 11% International (Non-Resident Alien), 7% Hispanic/Latino, 6% Unknown, 2% 2 or more races, 0% American Indian or Alaska Native.

Research Questions

RQ1: *At What Predominant Academic Levels (>10% Population) Do Engagements Happen and What Skills Are Self-Reported to Be Developed?*

Table 1 presents the breakdown of participants and the predominant timing (academic levels) of involvement across the engagement groups. The skills reportedly developed/used are listed for each engagement group. The skill values shown in Table 1 are a ratio of the total skills divided by the participant size. For example, in Table 1, 114 students only had a 1-time engagement that occurred during junior year. Of those, 91 or 80% (0.8) reported that skill A (critical thinking/problem solving) was used/developed. Color-shading is used to visually depict the frequency of professional competency from lower (red) to higher (green) values.

The dominant trends comprise students who either did multiple engagements in one year or had continuous engagement across multiple academic levels. Across engagement levels, junior year is always a predominant period of CECA engagement. As engagement levels reach high and very high, the timing of engagement becomes more distributed across years and often includes first-year involvement. Conversely, for medium engagement levels, the first year is not a predominant time for engagement. This suggests an opportunity to focus on understanding why first-year students are less often engaged in CECAs. Students do not report CECA engagement with gaps between engagement. We also find that groups with a lower engagement rate (1 or 2-3 engagements) reported less distributed participation, and more during junior, grade 12, or transition from sophomore to junior years. Groups with a higher engagement rate, on the other hand, have a participation profile that is more evenly spread out across academic levels and often spans from grade 12 to junior or first-year up to junior year. As engagements progress from 2-3 times to 6-11 times, the number of academic levels of involvement increases.

As the number of engagements increase, the more likely that an individual student is to report the development/use of a particular professional competency. However, there is potentially a diminishing return on skill development on a per-engagement basis for the highest level of engagement.

We see a deficit value (<1) for skills for all the 1-time participants and a portion of 2–3-time participants. This suggests that not all students are developing/engaging those skills. The duration of involvement may rule over the academic level at which the involvement took place.

As the number of engagements and subsequent academic levels of involvement increase, the total number of skills reported per person increases. Yet, relatively speaking, some skills that are engineering-focused are consistently under-scored regardless of the number of academic-level involvements. For example, skills B (design), C (computer technology), and D (engineering tools) are often under-scored relative to F (teamwork/collaboration), H (professionalism/work ethic), and E (oral/written communication).

RQ2: *What Are the Predominant Selections (>=10% Sample Size) of CECAs and What Skills Are Self-Reported to Be Developed?*

Table 2 presents the breakdown of participants and their predominant types of CECAs across the engagement groups. The skills gained for predominant types of involvement are listed for each engagement group. Color-shading is used to visually depict the frequency of low to high-value skills gained. Again, we wish the skill value to be larger and at least greater than 1.

We see a deficit value (<1) for skills gained (out of a list of 9) for all the 1-time participants and a portion of 2–3-time participants. This suggests that not all students are developing/engaging those skills. What is further surprising is that in the 2-3-time engagement group, the type combination of involvement for most skills (other than higher-level engineering B, C, and D skills) seems to not improve the value of skill gained. This may once more suggest that the period of involvement rules over the type(s) of CECA in which the involvement took place.

The results show that students more often engage in non-technical and technical work and less often in experiences like clubs or undergraduate research. Skills E (oral/written communication), F (teamwork/collaboration), and H (professionalism/work ethic) were developed more as engagement increased. For skills B (design), C (computer technology), and D (engineering tools) however, increased engagement frequency does not lead to similar increase rates in the development of those skills.

We might expect that as the number of engagements increases, the development of professional skills per individual would increase. However, on a per-engagement basis, the number of skills developed can show diminishing returns. For example, we see the average skills gained per student from 2-3 times of engagement to not be much different from the student group who engaged 4-5 times in Nontechnical & Technical & Clubs. When dividing the reported skills gained by the number of engagements, we find that effectively the 4–5-time engagement group developed fewer skills per co-curricular participation than the 2-3 time engagement group.

TABLE 1
PREDOMINANT ACADEMIC LEVELS AND SELF-REPORTED SKILLS DEVELOPED

Academic levels involved	Count per engagement group	Percentage engagement of the group	A. critical thinking/problem-solving	B. engineering design, including the use of relevant codes/standards	C. use of appropriate computer technology	D. use of engineering tools	E. oral/written communication	F. teamwork/collaboration	G. leadership	H. professionalism/work ethic/integrity	I. project/time management
Low: 1-time engagement											
Junior	114	33%	0.8	0.54	0.64	0.45	0.74	0.82	0.48	0.76	0.7
Grade 12	82	24%	0.51	0.16	0.16	0.15	0.55	0.79	0.54	0.54	0.38
Sophomore	80	23%	0.73	0.45	0.46	0.24	0.71	0.74	0.48	0.69	0.7
First Year	67	19%	0.61	0.24	0.25	0.16	0.61	0.79	0.45	0.69	0.58
Medium: 2-3-time engagement											
Sophomore and Junior	71	23%	1.83	1	1	0.85	1.72	1.85	1.31	1.85	1.46
Junior	39	12%	1.82	1.26	1.05	1.03	1.51	1.62	1.31	1.54	1.49
Grade 12	32	10%	1.06	0.09	0.28	0.06	1.41	1.88	1.31	1.25	1.0
High: 4-5-time engagement											
First-year and Sophomore and Junior	33	20%	2.94	1.3	1.7	1.3	3.09	3.64	2.24	3.06	2.3
Grade 12 and First-year and Sophomore and Junior	30	18%	2.73	1.93	1.83	1.33	3.2	3.67	2.27	3.53	3.0
Sophomore and Junior	22	13%	3.27	1.91	2	1.77	3.18	3.64	2.73	3.09	2.68
Very High: 6-11-time engagement											
Grade 12 and First-year and Sophomore and Junior	74	55%	4.64	2.05	2.66	1.97	6	6.82	4.43	5.85	4.59
First-year and Sophomore and Junior	17	13%	4.71	2.41	3.35	1.82	5.65	6.06	4.41	5.82	5

TABLE 2
PREDOMINANT CECA TYPE AND SELF-REPORTED SKILLS DEVELOPED

Types of CECAs students engaged	Count of engagements	Percentage engagement of the group	A. critical thinking/problem-solving	B. engineering design, including the use of relevant codes/standards	C. use of appropriate computer technology	D. use of engineering tools	E. oral/written communication	F. teamwork/collaboration	G. leadership	H. professionalism/work ethic/integrity	I. project/time management
1-time engagement (n=343)											
Nontechnical	137	40%	0.56	0.07	0.19	0.03	0.68	0.8	0.55	0.71	0.53
Technical	128	37%	0.88	0.73	0.71	0.52	0.77	0.77	0.48	0.8	0.77
2-3-time engagement (n=314)											
Nontechnical & Technical	54	17%	1.93	0.94	1.0	0.76	1.78	2.02	1.13	1.94	1.54
Nontechnical & Clubs	42	13%	1.21	0.36	0.4	0.26	1.74	2.05	1.36	1.6	1.19
Technical	38	12%	2.18	1.53	1.53	1.24	1.74	1.87	1.32	1.89	1.92
Nontechnical	36	11%	1.25	0.08	0.58	0.14	1.58	1.83	1.28	1.78	1.17
4-5-time engagement (n=165)											
Nontechnical & Technical & Clubs	23	14%	2.7	1.65	1.52	1.35	2.87	3.52	2.57	2.96	2.52
6-11-time engagement (n=135)											
Service & Technical & Clubs	27	20%	3.89	2.11	2.48	1.96	5.7	6.67	4.63	5.63	4.52
Nontechnical & Technical & Clubs	18	13%	4.5	1.94	2.33	1.44	5.33	6.33	4.33	5.72	4.11
Service & Nontechnical & Clubs	14	10%	3.86	0.71	0.57	0.71	5.64	7.07	5.14	5.36	3.64

DISCUSSION

The literature often suggests that higher student engagement in CECAs may improve persistence, professional competency development, and student identity formation as future engineers (Bergen-Cico & Viscomi, 2012; Burt et al., 2011; Elias & Drea, 2013). We explored the professional competency aspect by analyzing data from a cohort of students who participated in CECAs and self-reported their skill development, toward building evidence to support the examination of co-curricular policies and support structures necessary to make co-curricular a complement to the required curriculum (Lee & Matusovich, 2016). As this study considers data from engineering undergraduates at a large public institution, we anticipate that elements of this discussion will resonate with many peer institutions.

Generally, our findings appear to be in line with prominent academic theories that suggest more involvement (i.e., engagements) provide more opportunities for learning and skill development (Astin, 1999; Tinto, 1987). However, two important considerations have implications for the value of involvement. First, there may be points of *diminishing returns* for particular types and combinations of CECAs. Research to better inform specific learning and the "Goldilocks" level of engagement necessary to reach those outcomes would help to inform individual students and broader policies around CECAs. For example, research might investigate: the extent to which students recognize specific learning and its professional relevance (Ohland et al., 2011); or how students manage time and commitment levels to avoid over-involvement and burnout (Finelli, et al., 2012). Such understanding is necessary to find a balance between quantity and quality of involvement (Astin, 1999; Stirling & Kerr, 2015).

Second, *individualized* learning and development in co-curricular spaces may go beyond what any one person or institution may imagine. Enabling students to transfer learning and build connections between curricular and co-curricular engagements is important to a holistic education (Golden & Bass, 2007). Reflective tools that support students in aligning varied experiences through the lens of professional competencies are needed. These key ideas are further discussed through the lens of demographics, academic timing, and engagement type.

CECAs Through the Demographic Lens

An overview of student demographics followed by engagement and skill development is explored between groups of students who participated in CECAs at different rates, i.e., 1, 2-3 4-5, and 6-11 times. Students, with different aspirations, personal struggles (e.g., family, health), availability, and curricular commitments may come to participate in CECAs in their own ways. Yet, some general trends emerged (>=10% of the sample size) from student groups who reported different rates of engagement.

Our analysis of student learning demographics showed dominant (exhibited by >=10%) differences across engagement groups (Figures 1 and 2). As might be expected given the demographic makeup of engineering (Roy, 2019), White Males are the predominant group. However, from Figure 1, it is noted that as the number of CECA engagements increased Female participants' percentage exceeded the undergraduate population proportion, while Male participants fall below the population proportion. This may indicate that CECAs are particularly valued by women (Ro & Knight, 2016) and should be explored further as a potential pathway that encourages greater participation of women in engineering.

From Figure 2, it is noted that the reported participation by non-White students is often below the undergraduate population proportion. The race/ethnicity distribution of higher engagement groups became more predominantly white as compared to the lower engagement groups. This suggests that White students may have a consistent advantage in terms of their ability to participate in CECAs regardless of the number of engagements they wish to pursue. This may also include the ability to be more selective in what they pursue. Students from historically marginalized groups may encounter barriers to participation owing to interpersonal, intrapersonal, and institutional factors. These findings are congruent with other research highlighting the lack of diversity in engineering (Chubin et al., 2005; Ohland et al., 2011; Roy, 2019), which extends beyond the curriculum based on data in this study.

The primary implication from data considered through the demographic lens is a need to consider policies and structures within the academe to better support the involvement of students from all backgrounds in CECAs. If involvement in such activities is important to a holistic education (and potentially retention), it would be in the interest of the engineering discipline to investigate how CECAs can be more equitably engaged by all students. However, since activities that occur outside of the required curriculum are voluntary and outside the purview of administrators, allocating necessary resources for such investigation may not be prioritized.

CECAs Through the Academic Timing Lens

The variability in academic levels of involvement may undermine the quality and aggregate learning potential of any given engagement. For example, students who participate in a student club for several years might be expected to gain more from the experience as their responsibility and status in the club grows.

Students who engage at lower rates mostly do so at a later time in a particular academic window, i.e., Grade 12 or the last two years of undergraduate studies. Students who engage at a higher rate, on the other hand, mostly do so across years and academic levels. Research concerning how much co-curricular time impacts the evolution of students' identity and professional skills development could help us understand when students should make co-curricular commitments. This idea is captured by Astin with respect to quality involvement, recognizing time as a limited resource and the potential for overinvolvement that becomes counterproductive (Astin, 1999) (i.e., undesirable ethical behaviors (Finelli, et al., 2012).

We find here the basis for an argument that earning an engineering degree should be more than a four-year endeavor. Engineering curricula are often described in terms of their rigor and complexity or inflexibility, which does not ensure outcomes that benefit the field and may be to its detriment (Heileman, et al., 2019; Riley, 2017; Wankat & Oreovicz, 2015). At the institution where this study occurred, engineering programs exceed the necessary credit hours for a degree by at least four credit hours. Thus, students may find themselves overwhelmed, with little time, energy, or mental bandwidth for anything beyond class (Cross & Jensen, 2018; Jensen & Cross, 2021; Ramteke & Ansari, 2016). For some students, participation in CECAs late in the curriculum may reflect a recognition that they need some "resume building" experience, but engagement may be reduced to a transactional one.

In raising this possibility, we recognize that there is a not insignificant economic consideration for many students. Extending beyond four years will increase the overall cost of school for many, without a guaranteed financial counterbalance (e.g., paid co-op experience). However, the tradeoff between the quality of academic experience and the educational cost is one worth exploring. Especially as technological platforms that can defray some academic costs (e.g., online learning) and innovative educational practices (e.g., micro-credentialing) continue to mature.

CECA Type

Generally, as engagements increased, students self-reported gaining more professional skills in line with Astin's idea that higher engagement leads to higher learning development; but also there is evidence of diminishing returns (Astin, 1999). However, we generally cannot verify what learning occurs in what CECAs as a function of the activities that occur and community makeup. From an institutional perspective, this makes it difficult to provide specific forms of support (Lee & Matusovich, 2016). It also makes it difficult to leverage CECAs as possible credit-bearing engagements. For example, technical projects within clubs may engage students in specific learning that is equivalent to learning in elective courses.

To remedy this challenge may require changes to academic policies that allow certain forms of CECAs to be counted as learning experiences that replace required technical or non-technical courses in the required curriculum. These mechanisms often exist – e.g., independent study credit for participation in undergraduate research – but their implementation can be challenging to scale. The lack of structure around many CECAs and the fact that the locus of control lies more with students (rather than faculty) can make it difficult to leverage existing mechanisms (i.e., independent study) that would officially recognize the value of the experience. The implication is that we need to add the right amount of structure to informal learning experiences so that they can be recognized as "worthy" learning experiences while allowing control to remain with students.

In addition to student-recognized learning going unrecognized by the institution, there is also the possibility that certain learning is not recognized by students themselves. There may be professionally relevant skills that go unrecognized in CECAs because they are not obviously connected to or situated in engineering. For example, consider design-related skills like working with ambiguity, reasoning about uncertainty, and divergent-convergent thinking (Dym et al., 2005). These types of skills might be exercised in a wide variety of CECAs, including non-technical work and service engagements, but students may be less likely to recognize them and therefore they may be underreported (as could be the case in the data set explored here).

One way to help students to recognize the full value of CECA experiences is through the creation of case examples and guides around professional competencies. While not all CECAs may lend themselves to academic credit, helping students to recognize and relate learning across both technical and non-technical experiences is critical to their understanding of the sociotechnical nature of engineering practice. Introducing exemplars and socially constructing definitions and assessment conventions around professional skills within CECA activities may contribute to the quality of institutional programming and students' reflective learning.

Limitations

We acknowledge that our study comes with limitations. The data was collected from four years of one R1 institution in North America and so the findings are generalizable only to the data collected and analyzed and may not extend to other institutions. We also note that the self-reported nature of data is a limitation of our study. Some students miscategorized their engagements – e.g., some students included participation in intramural sports under the student club and engineering project micro-credential program. Some students may further underscore or overestimate their skill acquisition and so the self-reported nature of skills gained is prone to be deceptive and/or erroneous.

CONCLUSION

The literature posits that more frequent and diverse co-curricular and extra-curricular (CECA) engagement may lead to more learning and an improved academic experience. A key contribution of this work is an exploration of this idea through a longitudinal data set. We explored the using data from an annual professional development survey, analyzing a student cohort who reported participation in CECAs at different rates over four years. Results of our analysis showed that participation rates differ along demographic lines and that the timing of participation and aggregation of professional competencies can vary widely. This study constitutes a system-level analysis of CECAs in terms of their navigation by students and potential value in holistic education. We conclude that there is a general need for research that works to identify the "Goldilocks" level of involvement, as well as a need to support students more broadly in connecting their learning in and out of the classroom. Future work will seek to investigate these issues and to inform revisions to the professional development reflection survey to support these aims.

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REFERENCES

ABET. (2021). *Criteria for Accrediting Engineering Programs, 2020 – 2021*. Retrieved from https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/

Adams, R., & Felder, R. (2008). Reframing professional development: A systems approach to preparing engineering educators to educate tomorrow's engineers. *Journal of Engineering Education*, *97*(3), 239–240. https://doi.org/10.1002/j.2168-9830.2008.tb00975.x

Astin, A.W. (1999). Student involvement: A developmental theory for higher education. *Journal of College Student Development*, *40*(5), 518–529.

Bartkus, K.R., Nemelka, B., Nemelka, M., & Gardner, P. (2012). Clarifying the meaning of extracurricular activity: A literature review of definitions. *American Journal of Business Education (AJBE)*, *5*(6), 693–704. https://doi.org/10.19030/ajbe.v5i6.7391

Bergen-Cico, D., & Viscomi, J. (2012). Exploring the association between campus co-curricular involvement and academic achievement. *Journal of College Student Retention: Research, Theory & Practice*, *14*(3), 329–343. https://doi.org/10.2190/CS.14.3.c

Burt, B., Carpenter, D., Finelli, C., Harding, T., Sutkus, J., Holsapple, M., & Ra, E. (2011). Outcomes of engaging engineering undergraduates in co-curricular experiences. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. https://doi.org/10.18260/1-2--18498

Chaudhury, Z., Hossain, Z., & Gordon, E.K. (2019). Cultural diversity in undergraduate engineering education. *Journal of Global Education and Research*, *3*(1), 10–21. https://doi.org/10.5038/2577-509x.3.1.1044

Chubin, D., May, G., & Babco, E. (2005). Diversifying the engineering workforce. *Journal of Engineering Education*, *94*(1), 73–86. https://doi.org/10.1002/J.2168-9830.2005.TB00830.X

Coates, H. (2015). Working on a dream: Educational returns from off-campus paid work. *Journal of Education and Work*, *28*(1), 66–82.

Conference Board of Canada. (2000). *Developing your employability skills toolkit for the self-managing learner*. Retrieved from http://hdl.voced.edu.au/10707/156085

Conrad, C. (1982). Grounded theory: An alternative approach to research in higher education. *The Review of Higher Education*, *5*(4), 239–249.

Cross, K.J., & Jensen, K.J. (2018). Understanding student perceptions of stress as part of engineering culture. *Proceedings of the American Society of Engineering Education Conference & Exposition.* Retrieved from https://peer.asee.org/work-in-progress-understanding-student-perceptions-of-stress-as-part-of-engineering-culture.pdf

Dall’Alba, G., & Sandberg, J. (2006). Unveiling professional development: A critical review of stage models. *Review of Educational Research*, *76*(3), 383–412. https://doi.org/10.3102/00346543076003383

Doig, G. (2019). Student perceptions about participation in co-curricular engineering projects—An Institutional Study at Cal Poly San Luis Obispo. *Hawaii International Conference on Education*, pp. 895–920.

Dym, C., Agogino, A., Eris, O., Frey, D., & Leifer, L. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103–120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Elias, K., & Drea, C. (2013). The Co-Curricular Record: Enhancing a Postsecondary Education. *College Quarterly*, *16*(1).

Evans, C. (2013). Making sense of assessment feedback in higher education. *Review of Educational Research*, *83*(1), 70–120. https://doi.org/10.3102/0034654312474350

Finelli, C., Holsapple, M., Ra, E., Bielby, R., Burt, B., Carpenter, D., & Sutkus, J. (2012). An assessment of engineering students’ curricular and co-curricular experiences and their ethical development. *Journal of Engineering Education*, *101*(3), 469–494. https://doi.org/10.1002/j.2168-9830.2012.tb00058.x

Finelli, C.J., Holsapple, M.A., Ra, E., Bielby, R.M., Burt, B.A., Carpenter, D.D., . . . Sutkus, J.A. (2012). An assessment of engineering students’ curricular and co-curricular experiences and their ethical development. *Journal of Engineering Education*, *101*(3), 469–494. https://doi.org/10.1002/j.2168-9830.2012.tb00058.x

Foubert, J., & Urbanski, L. (2006). Effects of involvement in clubs and organizations on the psychosocial development of first-year and senior college students. *NASPA Journal*, *43*(1), 166–182. https://doi.org/10.2202/1949-6605.1576

Freeman, K., Ellis, M., Parham-Mocello, J., & Walker, H.M. (2020). Panel: Supporting student co-curricular experiences. *1st ACM Technical Symposium on Computer Science Education*, pp. 641–642.

Golden, E., & Bass, L. (2007). Creating meaningful assessments for professional development education in software architecture. *20th Conference on Software Engineering Education & Training (CSEET’07)*, pp. 283–290. https://doi.org/10.1109/CSEET.2007.16

Heileman, G.L., Thompson-Arjona, W.G., Abar, O., & Free, H.W. (2019). Does curricular complexity imply program quality? *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. Retrieved from https://peer.asee.org/32677

Heller, R., Beil, C., Dam, K., & Haerum, B. (2010). Student and faculty perceptions of engagement in engineering. *Journal of Engineering Education*, *99*(3), 253–261. https://doi.org/10.1002/j.2168-9830.2010.tb01060.x

Henderson, T. (2017). Exploring the post-graduation benefits of high-impact practices in engineering: Implications for retention and advancement in industry. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. Retrieved from https://peer.asee.org/28340

Jamison, C.S.E., Huang-Saad, A., Daly, S.R., & Lattuca, L.R. (2020). The value of co-curricular experiences: Perspectives of third-year biomedical engineering students. *Proceedings of the American Society of Engineering Education Annual Conference & Exposition.* Retrieved from https://peer.asee.org/35381

Jensen, K.J., & Cross, K.J. (2021). Engineering stress culture: Relationships among mental health, engineering identity, and sense of inclusion. *Journal of Engineering Education*, *110*(2), 371–392.

Knight, D., & Novoselich, B. (2017). Curricular and co-curricular influences on undergraduate engineering student leadership. *Journal of Engineering Education*, *106*(1), 44–70. https://doi.org/10.1002/jee.20153

Krause, S., Middleton, J., Judson, E., Ernzen, J., Beeley, K., & Chen, Y. (2015). Factors impacting retention and success of undergraduate engineering students. *Proceedings of the American Society of Engineering Education Annual Conference & Exposition.* Retrieved from https://peer.asee.org/24095

Kuh, G.D. (2008). *High-Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter*. American Association of Colleges & Universities.

Lee, W., & Matusovich, H. (2016). A model of co-curricular support for undergraduate engineering students. *Journal of Engineering Education*, *105*(3), 406–430. https://doi.org/0.1002/jee.20123

Lutz, B., & Marie, C. (2021). Exploring the Social and Cultural Dimensions of Learning for Recent Engineering Graduates during the School-to-Work Transition. *Engineering Studies*, *13*(132).

Male, S.A. (2010). Generic engineering competencies: A review and modelling approach. *Education Research and Perspectives*, *37*(1), 25–51.

Millunchick, J., & Zhou, Y. (2020a). The Effect of Clusters of Participation in Engineering Co-curricular Activities on Student Outcomes. *Proceedings of the American Society of Engineering Education Annual Conference & Exposition*. Retrieved from https://peer.asee.org/35305

Millunchick, J., & Zhou, Y. (2020b). What Affects Student Outcomes More: GPA or participation in co-curricular activities? *Proceedings of the American Society of Engineering Education Annual Conference & Exposition*. Retrieved from https://peer.asee.org/35496

Muldoon, R. (2009). Recognizing the enhancement of graduate attributes and employability through part-time work while at university. *Active Learning in Higher Education*, *10*(3), 237–252. https://doi.org/10.1177/1469787409343189

OECD. (2005). *The definition and selection of key competencies: Executive summary*. Retrieved from https://www.oecd.org/pisa/definition-selection-key-competencies-summary.pdf

Ohland, M., Brawner, C., Camacho, M., Layton, R., Long, R., Lord, S., & Wasburn, M. (2011). Race, gender, and measures of success in engineering education. *Journal of Engineering Education*, *100*(2), 225–252. https://doi.org/10.1002/j.2168-9830.2011.tb00012.x

Ohland, M., Sheppard, S., Lichtenstein, G., Eris, O., Chachra, D., & Layton, R. (2008). Persistence, engagement, and migration in engineering programs. *Journal of College Student Development*, *97*(3), 259–278.

Passow, H.J., & Passow, C.H. (2017). What competencies should undergraduate engineering programs emphasize? A systematic review. *Journal of Engineering Education*, *106*(3), 475–526. https://doi.org/10.1002/jee.20171

Ramteke, I.V., & Ansari, J. (2016). Stress and Anxiety among first-year and final year engineering students. *Stress*, *3*(4), 17–21.
Reason, R.D. (2009). An examination of persistence research through the lens of a comprehensive conceptual framework. *Journal of College Student Development*, *50*(6), 659–682.
Riley, D. (2017). Rigor/Us: Building boundaries and disciplining diversity with standards of merit. *Engineering Studies*, *9*(3), 249–265.
Ro, H., & Knight, D. (2016). Gender differences in learning outcomes from the college experiences of engineering students. *Journal of Engineering Education*, *105*(3), 478–507.
Roy, J. (2019). *Engineering by the Numbers*. American Society for Engineering Education.
Rutter, M.P., & Mintz, S. (2016). The curricular and the co-curricular. *Inside Higher Ed*. Retrieved from https://www.insidehighered.com/blogs/higher-ed-gamma/curricular-and-co-curricular
Shuman, L., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "Professional Skills" – Can They Be Taught? Can They Be Assessed? *Journal of Engineering Education*, *94*(1), 41–55. https://doi.org/10.1002/j.2168-9830.2005.tb00828.x
Smith, K.A., Sheppard, S., Johnson, D., & Johnson, R. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education*, *94*(1), 87–101. https://doi.org/10.1002/j.2168-9830.2005.tb00831.x
Stirling, A., & Kerr, G. (2015). Creating meaningful co-curricular experiences in higher education. *Journal of Education & Social Policy, 2*(6), 1–7.
Tinto, V. (1975). Dropout from higher education: A theoretical synthesis of recent research. *Review of Educational Research*, *45*(1), 89–125.
Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition* (2nd Ed.). University of Chicago Press.
Turrentine, C., Esposito, T., Young, M., & Ostroth, D. (2012). Measuring educational gains from participation in intensive co-curricular experiences at Bridgewater State University. *The Journal of Assessment and Institutional Effectiveness*, *2*(1), 30–54. https://doi.org/10.5325/jasseinsteffe.2.1.0030
Wankat, P.C., & Oreovicz, F.S. (2015). *Teaching engineering*. Purdue University Press.