Using Directional Graphs to Explore the Engineering Co-curricular Navigation Profiles of Student Groups

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Introduction

The goal of this work-in-progress (WIP) paper is to explore the use of a visual method to synthesize the co-curricular navigation profiles of student groups over time. Specifically, in this work, we consider the navigation profiles of three groups of students who continually scored low, medium, and high GPAs over four years. We find there to be a gap in studying the interplay of students' co-curricular involvement and GPAs. On the one hand, students' participation in co-curricular activities can be important to their development and persistence [1], [2]. On the other hand, the more students participate in co-curriculars the less time they have available to study and excel in the curricular space. This duality motivates our research question: What are the co-curricular navigation characteristics of student groups who continually score low, medium, and high GPAs over their undergraduate studies? We use student GPAs as they are commonly regarded as an indicator of student success in curricular spaces. Further, using GPAs is convenient because they are easily trackable by the institution while other measures of success are less so.

There are divergent findings about the interplay of student GPA (curricular performance) and learning development in co-curricular spaces. Work by Bergen-Cico & Viscomi (2012) on the analysis of GPA by attendance rate clusters showed that students attending 5-14 co-curricular events over a set number of semesters had significantly higher ($p < 0.001$) GPAs than students attending fewer or more events [3]. Work by Leung suggests that participation is not necessarily an indicator of enhancing the learning effectiveness and grades of the students [4]. This may be because the main objective of the students is either focusing on their curricular duties or co-curricular activities during the term. However, the authors found that the timing of engagement in co-curricular activities could influence learning effectiveness. Given the diversity of findings, we find it necessary to devise methods that can allow studying the interplay of GPA and co-curricular involvement further.

We also find there to be a gap in the way student co-curricular navigation is studied. Often the analysis of student co-curricular participation is limited to high-level summaries such as total engagements across groups without visually probing into the navigation profiles of student participation. This understanding needs to move beyond a headcount of participation that is often reflected in institutional reports and examine what type and arrangements of co-curricular experiences the students of different groups come to participate in their studies. Thus here, we explore the potential of visual representations to support understanding. The work is inspired by Social Network Analysis (SNA) in educational research. SNA is a visual method that is used in social sciences. It is a theoretical field that primarily focuses on network structures (e.g., connections of individuals in social a setting) through visual depiction as well as statistical and mathematical characterization [5]. It is predominantly used for modeling and predicting community networks' associations or themes of expressions. Prior work in education has used SNA to examine interactions between and within user groups (e.g., students, tutors, and instructors) [6]–[8]. To our understanding, no visual approach that portrays the co-curricular

navigation profiles of students against their curricular performance has been conducted. This gap inspires our work to use directional graphs, a primary tool in SNA. In this WIP we explore the interplay of curricular performances and co-curricular navigation profiles through directed graphs as a possible scenario of deeper study.

Methods

A directed graph enables a visual representation of the movement of students from one co-curricular activity to another using nodes (filled-in circles that encapsulate the co-curricular type) and edges (arrows that connect nodes and can signify the chronology of participation). Each student has a directed graph which may vary in the number of nodes and edges. This exploratory work considers visual analysis and shares the navigation profiles of a small student sample, rather than making inferences for demographic populations. We evaluate the co-curricular participation profiles through visual means surrounding three groups of students engaging in various co-curricular activities: 1. Nontechnical (e.g., retail store clerk), 2. Service (e.g., community volunteer), 3. Student Clubs (e.g., Society of Automotive Engineering), 4. Makerspace/Engineering project micro-credential (i.e., Makerspace), 5. Undergraduate Research (e.g., summer REU), 6. Technical (e.g., engineering internship). We rounded and categorized students into three groups of low, medium, and high GPAs. Students were placed in GPA bins of low, medium, and high as follows: 1 (low) =1.0 to 2.32, 2 (med) =2.33 to 3.32, and 3 (high) =3.33 to 4.0.

The types and order of co-curricular participation of students were collected from an annual professional development survey (PDS, self-reported by the students) while the GPA of students per terms of involvement was tracked by the institution. We utilized purposeful sampling and considered data from students between 2015-2018 who were reporting on their first-, second-, and third-year experiences during these four years. Each year students report on their experiences from the previous year. Students may have participated in different types of co-curricular(s) once or many times. We drew a random sample of five students from each group and took a closer look at the individual profiles of co-curricular participation over time between the low, medium, and high GPA groups. We ensured the student was either a first year, sophomore, or junior (we excluded those reporting to be in grade 12 to focus on the undergraduates' experiences) during 2015-2018 and had consistently scored a cumulative GPA within the above ranges. A summary of student data used in this WIP can be found in the Appendix.

Table 1. Sample student (student 4) data belonging to the medium GPA group.

The types of engagements	The year in which the student participated	PDS Semester(s)The semesters in which the student participated	Academic level	The number of co-curricular engagements reported	GPA bin
Clubs, Service, Technical, Research,	2015-2016, 2015-2016, 2016, 2016	Fall-15 & Winter-16 & Spring-16 & Summer-16, Fall-15 & Spring-16, Summer-16, Summer-16,	junior, junior, junior, junior,	4	Medium

To provide some context on how the graphs are created, refer to the sample student data shown in Table 1. As can be seen, this student reported participating in four types of co-curricular experiences, namely Clubs, Service, Technical, and Research from fall 2015 through summer 2016. The semesters in which the student participated column reports on the semesters of involvement per each type of engagement (e.g., the student reported Club engagement in fall, winter, spring, and summer). The data was used to construct the directional graph of Figure 1. The arrows presented in a vertical orientation depict the flow of participation over time. The text beside each co-curricular depicts the year(s) the student participated in - their academic level that year – and the total number of semesters of involvement.

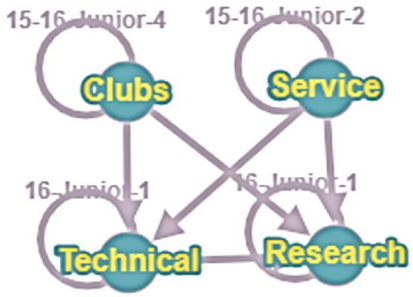

Figure 1. Sample student data (student 4 belonging to the medium GPA group)

Results and discussion

The co-curricular navigation profiles of five students from each of the low, medium, and high GPA groups are shown in Figures 2-4, respectively. The graphs depict student selection and navigation of one or multiple co-curricular experiences. Note some of the semiologies of the directional graphs adopted:

- S1-S3 in Figure 2, S1 and S3 in Figure 3, and S2 in Figure 4 had no arrows, depicting that student engagements happened at one instance of time only (i.e., the same semester).
- S4-S5 in Figure 2, S2 and S5 in Figure 3, and S4 and S5 in Figure 4 mostly made engagements sequentially across semesters and years.
- S4 in Figure 3, S1 and S3 in Figure 5 mostly made engagements in parallel across semesters and years.

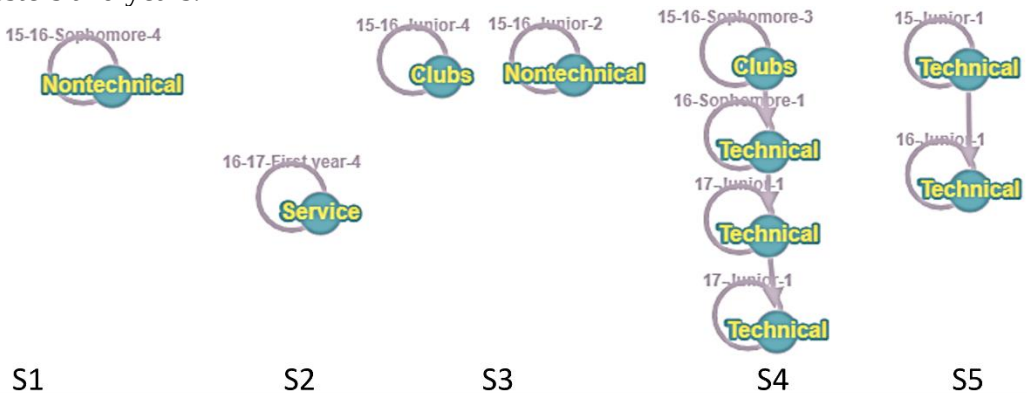

Figure 2. Co-curricular navigation profile for students 1 – 5 in the low GPA group

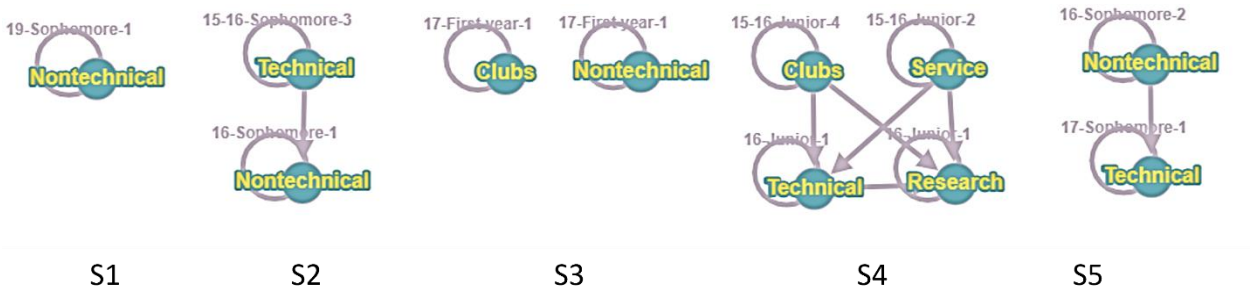

Figure 3. Co-curricular navigation profile for students 1 – 5 in the medium GPA group

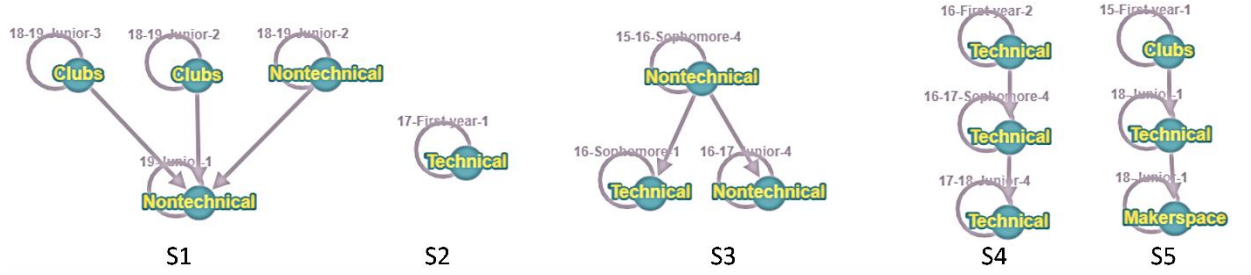

Figure 4. Co-curricular navigation profile for students 1 – 5 in the high GPA group

Though our analysis is limited in depth and therefore not generalizable to the entire population, we hope that the method in conjunction with the use of data science practices enables a more rigorous analysis of co-curricular participation in engineering education. While exploratory, this WIP, in the context of students studied, reveals some themes from the graphs, which are briefly described here as examples.

Finding trends through visual exploration

- The low GPA group had the most (3/5) and the high GPA group had the fewest (1/5) number of students engaging in co-curricular at one instance of time only. Conversely, the number of semesters per one-time engagement was highest for the low GPA group and the least for the medium and high GPA groups. For the low and medium GPA groups, the one-time engagements were mostly nontechnical and club experiences. For the high GPA group, this was a technical experience.
- The high GPA group has the highest (4/5) and the low GPA group has the least (2/4) number of technical engagements. The low GPA group had spent 1 semester in technical experiences. The semesters of involvement for medium and high GPA was variable.
- Students in all three groups tend to do multiple co-curricular experiences in a given year rather than the span of four years. Most do so in their sophomore or junior year.
- Nontechnical and Technical experiences are often looped (i.e., repeated co-curricular type back-to-back)
- Research, Makerspace, and Service are less frequently engaged

Visual presentation informing co-curricular programming

We also find the directional graphs can provide insight into potential issues in the way student co-curricular experiences are completed and their data is collected. Here we draw the reader's attention to some sample participations:

- Student 4 in Figure 2 the low GPA group: This student reported starting with Clubs followed by Technical experiences in their sophomore year in 2015 and then completing two technical experiences in 2016 as a junior student. In the future, it is worth coding and classifying the role and employers of students to find out whether such students: a) did all their technical experiences in one company, b) if done in the same company whether the roles are all the same or rotations were being made, and c) whether the student reported one technical experience multiple times.
- Student 4 in Figure 3 medium GPA group: This student reported participating in 4 types of co-curricular experiences throughout 2015 as a junior student. It is unlikely that the breadth and depth of these experiences are similar to a student who does only one type of co-curricular in the same time period. Surveying students with such brief and heavy participation can help find the motivation behind it and also determine students' satisfaction and learning outcomes.
- Student 2 in Figure 4 the high GPA group: The student completed a technical experience in their first year for one semester only. It is worth exploring the nature of the employment and students' GPAs who participate in such (brief) technical jobs.

Limitations with the visual presentation

A limitation of the visual representation is the way the timing of co-curricular participation is populated in the graphs. Future co-curricular directional graphs need to visually present the duration in the dimension of time as well. This could happen, for example by representing the duration of each co-curricular through their relative size. Color coding can also be used to differentiate between two different instances of involvement in one type of co-curricular experience versus one instance of involvement in one type of co-curricular experience that was spread across different times. Timing and coordination is known to play a key role in engineering [4], The preliminary findings encourage exploring student curricular (unavailable for our study) in conjunction with their co-curricular participation profiles in future work. Finally, it may be more valuable to consider undirected graphs to look across student navigation profiles and filter on various demographic or other characteristics (e.g., GPA) find patterns in the co-curricular navigational profiles.

Conclusion

In this work-in-progress paper (WIP) we present directional graphs and offer a visual analysis surrounding engineering student engagements in co-curricular experiences. The contribution of this WIP is in exploring the interplay of curricular performances and co-curricular navigation profiles through visually intuitive means.

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Appendix: Data used to generate directed graphs

Student #		The year in which student participated	The semesters in which student participated	Academic level	The number of co-curricular engagements reported	GPA bin
	Low GPA Group					
S1	Nontechnical,	2015-2016,	Fall-15 & Winter-16 & Spring-16 & Summer-16, 2159 2160 2161 2166,	sophomore,	1,	Low
S2	Service,	2016-2017,	Winter-16 & Fall-16 & Spring-17 & Summer-17 2160 2169 2171 2176,	first year,	1,	Low
S3	Clubs,Nontechnical,	2015-2016, 2015-2016,	Fall-15 & Winter-16 & Spring-16 & Summer-16, Fall-15 & Spring-16 2159 2160 2161 2166,2159 2161,	junior,junior,	2,	Low
S4	Clubs,Technical,Technical,Technical,	2015-2016, 2016, 2017, 2017,	Fall-15 & Spring-16, Summer-16, Spring-17, Summer-17 2159 2161,2166, 2171,2176,	sophomore, sophomore, junior,junior,	4,	Low
S5	Technical,Technical,	2015, 2016,	Fall-15, Summer-16 2159,2166,	junior, junior,	2,	Low

	Medium GPA Group					
S1	Nontechnical,	2019,	Summer-19 2196,	sophomore,	1,	Medium
S2	Technical,Nontechnical,	2015-2016, 2016,	Fall-15 & Winter-16 & Spring-16, Summer-16, 2159 2160 2161,2166,	sophomore, sophomore,	2,	Medium
S3	Clubs,Nontechnical,	2017, 2017,	Spring-17, Spring-17 2171,2171,	first year, first year,	2,	Medium
S4	Clubs,Service,Technical,Research ,	2015-2016, 2015-2016, 2016, 2016,	Fall-15 & Winter-16 & Spring-16 & Summer-16, Fall-15 & Spring-16, Summer-16, Summer-16, 2159 2160 2161 2166, 2159 2161,2166,2166,	junior, junior, junior, junior,	4,	Medium
S5	Nontechnical, Technical,	2016, 2017,	Winter-16 & Fall-16, Spring-17 2160 2169, 2171,	sophomore, sophomore,	2,	Medium

	High GPA Group					
S1	Clubs,Clubs,Nontechnical,Nontechnical,	2018-2019, 2018-2019, 2018-2019, 2019,	Fall-18 & Spring-19 & Summer-19, Fall-18 & Spring-19, Fall-18 & Spring-19, Summer-19 2189 2191 2196,2189 2191,2189 2191,2196,	junior, junior, junior, junior,	4,	High
S2	Technical,	2017,	Fall-17 2179,	first year,	1,	High
S3	Nontechnical, Technical, Nontechnical,	2015-2016, 2016, 2016-2017,	Fall-15 & Winter-16 & Spring-16 & Summer-16, Summer-16, Winter-16 & Fall-16 & Spring-17 & Summer-17 2159 2160 2161 2166, 2166, 2160 2169 2171 2176,	sophomore, sophomore,junior,	3,	High
S4	Technical,Technical,Technical,	2016, 2016-2017, 2017-2018,	Winter-16 & Summer-16, Winter-16 & Fall-17 & Spring-17 & Summer-17, Winter-17 & Fall-17 & Spring-18 & Summer-18 2160 2166, 2160 2169 2171 2176, 2170 2179 2181 2186,	first year, sophomore,junior,	3,	High
S5	Clubs,Technical, Makerspace,	2015, 2018, 2018,	Fall-15, Spring-18, Summer 18 2159,2181,2186,	first year,junior,junior,	3,	High