Assessing Community in an Undergraduate Computer Science Program Using Social Network Analysis

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***Abstract*—Sense of community and belonging represent key components of students' success in undergraduate degree programs. As part of a curriculum effort designed to strengthen these components, we conducted a Social Network Analysis of students in an undergraduate computer science program to establish a baseline measurement of students' connectedness in the program. Analysis of these data showed no significant differences in connectedness between male and female students or white and non-white students. The analysis did identify significant differences based on students' class year, interest and participation in computer games, and being employed by the computer science department.**

Keywords—Social Network Analysis, community, belonging

I. Introduction

The research presented in this paper is part of a curriculum reform effort to transform undergraduate education in a Computer Science department by replicating the most effective elements of a software company environment combined with the infusion of moral, ethical, and social foci with entrepreneurship and professional skills. This effort seeks to create a curriculum and environment that produces graduates with the experience, training, and skills necessary to swiftly integrate into software company workflow and influence culture. Computer science curricula often focus nearly exclusively on technical skills and knowledge, while concentrating critical professional skills such as ethics and teamwork in a single course — a phenomenon that weakens the appearance such skills are essential elements of professional practice, and reduces students' ability to incorporate those skills into their repertoire. Issues of inclusivity and teamwork lack integration in the curriculum, so long-standing social biases and cultural problems in the profession continue to be propagated. This can lead to a lack of community and sense of belonging in computer science, particularly for women and underrepresented minorities.

To address this lack of community, we developed a progressive academic curriculum structure where students at all grade levels work with each other. This includes three primary curricular innovations: (1) Infusion of ethics and social justice principles, starting at the first course taken by first-year CS majors and continuing throughout the curriculum. By infusing ethical and moral elements into the practice of software engineering for our students, we empower our students to be agents of change in reshaping the culture and practice of computer science to be a more inclusive profession. (2) Short, narrowly focused, agile courses are threaded with regular course work and are used to both reinforce foundational concepts and skills at key points in the curriculum. These courses also provide create greater opportunities for students to interact and collaborate across grade levels, resulting in (3) vertically integrated teaching and learning. Instead of being in siloes, students at all grade levels work with and learn from each other on industry-sponsored projects, fostering a strong sense of community amongst students, faculty, and industry.

To understand the effectiveness of these changes, we needed a way to measure community and sense of belonging of undergraduate students in our computer science department. Using Social Network Analysis (SNA) techniques, we explore the current baseline state of our undergraduate computer science community, and how students' connections within this community vary based on demographic and other factors.

II. Background

Educators and educational researchers have long recognized the relationship between students' sense of belonging to a community and learning, formalized in the work of Vygotsky[1] and others taking a social constructivist approach to student learning. Students' sense of belonging (or lack thereof) is a strong predictor of success and persistence in university STEM degree programs[2], particularly for women and underrepresented minorities[3], [4].

Social Network Analysis is a powerful tool for understanding relationships among social entities, and identifying patterns within these relationships[5]. SNA is a well utilized tool in educational research and has been used in numerous studies of engineering and computer science education. These include research projects diverse as exploring the role of race and gender in the social structure of a first-year engineering course[6], describing the effects of computer supported collaborative learning[7], group decision making dynamics[8], and distributed cognition and collaborative learning[9].

Given the ability of Social Network Analysis to characterize relationships between individuals, it is a useful tool for understanding the structure and formation of community in educational environments. As part of a mixed methods study that included SNA, Dawson[10] found that degree, a measurement of network centrality, and betweenness, a measurement of network distance, were both correlated with students' reported sense of community in education courses at a university. A study of a physics learning center[11] found that while time spent in the center and student major both predicted students' participation in the learning community, neither gender nor race/ethnicity were predictive. The authors use these results to assert that the physics learning center represented an equitable and welcoming educational community. Another study of the social networks of students in distributed learning communities also found a strong relationship between measurements of the strength of students' social networks and their performance in a multidisciplinary engineering program[12]. The authors suggest several reasons for this correlation, including access to a wider range of resources, earlier and greater awareness of opportunities, and efficient access to knowledge and better sharing of tacit knowledge.

III. Methods

A. Data Collection

We collected social network data using a Qualtrics online survey that we developed specifically for this purpose. The survey asked the respondents to indicate up to ten computer science students who they felt most connected to, and how they characterized the relationship. Options for describing the relationships included asking the person for help, being asked for help by the person, considering the person a friend, considering the person a leader, and gaming with the person. The survey also collected respondents demographic information, including race/ethnicity, sex, current class year, and characteristics associated with non-traditional student status such as being a parent or caregiver or a part time student. All currently enrolled computer science majors (N=697) received a link to participate in the survey, of which n=244 students responded yielding an overall response rate of 35%. Respondents received a small amount of extra credit (0.1%) in the CS course of their choosing to incentivize participation.

B. Data Analysis

After exporting and cleaning the data, we utilized the igraph package in R for analysis. For this research, we focused on exploring degree, defined as the number of connections of each individual in the network. Social network data typically do not meet normality requirements, therefore we utilized the Kruskal-Wallis (KW) non-parametric test to compare differences in degree between various subpopulations. When comparing three or more groups, we utilized Dunn's post-hoc test with Benjamini-Hochberg correction to determine which differences between groups were statistically significant.

IV. Results

A. Gender

Table I shows descriptive statistics for degree by gender, and indicates that male and female students have similar levels of connectedness, with both having a median degree of 9 connections and KW test indicating no significant difference between them ($\chi^2(1) = 0.03$, $p = 0.9$). Although women comprise a much smaller proportion of the undergraduate CS population than their male peers, this does not have any effect on their connectedness.

TABLE I. Differences in Degree by Gender

	Male	Female
n	184	47
Mean	9.11	9.49
Standard Deviation	5.56	6.23
Median	9	9
Min	1	1
Max	28	27
Skew	0.71	0.71
Kurtosis	0.37	0.05

B. Race/Ethnicity

Table II shows descriptive statistics for degree by race/ethnicity, and indicates that while non-white students have slightly higher median degree (10.5 versus 8) the KW test yielded no significant difference between them ($\chi^2(1) = 2$, $p = 0.1$). Similar to the comparison of male and female students, despite non-white students comprising a much smaller proportion of the undergraduate CS population than their white peers, this does not have any effect on their connectedness.

TABLE II. Differences in Degree by White/Non-White

	Non- White	White
n	40	194
Mean	10.07	8.95
Standard Deviation	5.34	5.68
Median	10.5	8
Min	1	1
Max	21	28
Skew	0.02	0.83
Kurtosis	-1.05	0.62

C. Class Year

Table III shows descriptive statistics for degree by class year, and indicates differences in degree, with KW testing showing these differences as significant ($\chi^2(4) = 30$, $p < 0.001$). We used Dunn's post-hoc test with Benjamini-Hochberg correction to determine which differences are significant, the results of which are shown in Table IV. These results indicate that students tend to increase their number of connections as they progress through their undergraduate education, with 4th year (senior) students having the highest median degree and students in their 5th year exhibiting a statistically significant drop in median degree. This may indicate 5th year students not being as strong a cohort due to being comprised of students who may have failed or repeated a course, transferred into the major, or part-time or otherwise non-traditional students.

It is also worth noting that 1st year students reported a median degree of only four connections, indicating that they do not feel connected to many other CS students. While this lack of connection is somewhat concerning, it may just be due to these students being new to both the university and the CS program, with many having taken only one computer science class.

TABLE III. DIFFERENCES IN DEGREE BY CLASS YEAR

	1st Year	2nd Year	3rd Year	4th Year	5th Year or more
n	29	59	74	43	29
Mean	5.21	7.97	10.12	12.02	8.69
Standard Deviation	3.79	4.92	5.58	6.01	5.42
Median	4	8	10	12	9
Min	1	1	1	1	1
Max	16	21	27	28	20
Skew	1.17	0.56	0.69	0.56	0.26
Kurtosis	0.52	-0.3	0.25	0.43	-1.16

TABLE IV. SIGNIFICANCE OF DIFFERENCES BY CLASS YEAR

	1st Year	2nd Year	3rd Year	4th Year
2nd Year	-2.419 0.031*			
3rd Year	-4.246 0.000*	-2.186 0.041*		
4th Year	-5.167 0.000*	-3.455 0.002*	-1.624 0.1305	
5th Year or more	-2.610 0.023*	-0.603 0.5467	1.117 0.2931	2.315 0.034*

a. Top number indicates pairwise z-Test value, bottom number is adjusted *p*-value based on Benjamini-Hochberg correction

*indicates significance (p<0.05)

D. Gamer

Interest in video games can be both a motivator for students to pursue an undergraduate CS degree, and a way to socialize and bond with peers in the program[13], leading us to include gaming as one of the possible relationships that students could indicate in the social network survey. Table V show descriptive statistics for degree based on whether or not respondents played video games with their peers, with KW testing indicating the differences between these two groups as significant ($\chi^2(1) = 70$, $p < 0.001$). With a median degree of 8, gamers tend to be much more connected than their non-gaming peers with median degree of 2. Gamers also comprised a significant portion of the undergraduate CS population, with respondents identifying 159 people as gamers of the 475 unique individuals included in the network, or around 33% of the network.

TABLE V. DIFFERENCE IN DEGREE BY GAMING

	Non-Gamer	Gamer
n	303	157
Mean	4.43	8.55
Standard Deviation	4.72	5.88
Median	2	8
Min	1	1
Max	27	28
Skew	1.86	0.79
Kurtosis	3.46	0.33

E. Computer Science Department Employees

Table VI shows descriptive statistics for degree by students' employment status within the CS department, and indicates that CS department employees tend to have significantly more connections to other CS students (median degree of 11.5 versus 3 for non-employees), and this difference is statistically significant ($\chi^2(1) = 30$, $p < 0.001$). This quantitatively demonstrates the important role of teaching assistants in building connections and community among undergraduate computer science students. Despite only identifying 36 of the 475 unique individuals included in the network being CS department employees (identified via departmental records), these individuals play an outsized role in building connections in the CS department, and serve an important role both in potentially building connections across grade levels and providing a connection for first-year students to the computer science undergraduate community.

TABLE VI. DIFFERENCES IN DEGREE BY DEPARTMENT EMPLOYMENT STATUS

	Non-Employee	Employee
n	424	36
Mean	5.29	12.33
Standard Deviation	4.8	8.41
Median	3	11.5
Min	1	1
Max	21	28
Skew	1.12	0.35
Kurtosis	0.3	-1.15

V. CONCLUSION

Based on the analyses of our social network data, we found that there were no meaningful differences in the connectedness of male versus female students, or white versus non-white students. This can indicate either that these minority groups are well-integrated in the computer science department, or at the very least have developed equivalently strong social networks as their majority peers. This contradicts a large body of prior research showing that women and especially people of color tend to not be as well integrated in STEM as their white male peers [14], [15] and suggests the need for further inquiry to better understand the connectedness of non-majority students to the undergraduate computer science community.

We did identify significant differences in the connectedness of several subgroups in undergraduate computer science. Students' connectedness increases through the four years of their undergraduate education, however students in their fifth year or more of studies tended to be less connected than traditional seniors in their fourth year. Students spending more time together, taking more classes together, and having class schedules comprised of a greater proportion of CS classes all represent plausible explanations for the increase in connectedness. However, this may also be due to a lack of persistence of students who do not feel connected to the undergraduate CS community. This presents an interesting opportunity for future research. Fifth year and beyond students may be less connected than traditional seniors for a variety of reasons such as leaving their original cohort due to failing classes, and personal or financial issues that may have forced these students to take fewer classes per semester. Again, this presents an opportunity for further study.

The results of this study provide quantitative evidence of the role of gaming in developing community among undergraduate CS students. Students who identified themselves or their peers as gamers tended to have significantly more connections than their non-gaming classmates. In addition to providing a shared social activity, gaming also can provide a network of individuals to study with and reinforce in-person relationships in a virtual space. In related research, we have also found that students utilize gaming technologies and reach out to their gaming friends to collaborate on class assignments and seek advice about the professional practice of computer science. Gaming can be a significant source of cultural capital for computer science, but one that is not necessarily open to all students equally due to a combination of lack of interest and the closed nature of some gaming communities.

Finally, this study also quantitatively demonstrates the importance of teaching and learning assistants in creating community in the CS department. While small in number (less than 10% of the total network), these individuals have an outsized impact in building connections in the undergraduate CS community and further support the value of peer tutors.

In addition to the aforementioned need to further explore the results of this study as they apply to women and people of color, we also plan to explore how differences in degree and other measures of connectedness among undergraduate computer science students influence their academic and professional outcomes such as grades, persistence in the degree program, and career pathways.

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