

Developing an Instrument to Understand the Social-Structural Integration of Diverse Students

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Introduction

The purpose of this research paper is to present the development of a social networking survey, for use in a large-enrollment, multi-section, first-year engineering design course, to better understand how diverse students are integrated into the social structures. Engineering educators are challenged to bring more people into engineering and broaden the pool from which they recruit. For the United States is to remain a global leader in the fields of Science, Technology, Engineering, and Mathematics (STEM), “then it must produce approximately 1 million more STEM professionals over the next decade than are projected to graduate at current rates.”¹ While engineering makes up only a portion of this demand, it has substantial room for growth especially from traditionally underrepresented groups.²⁻⁴ Undergraduate engineering enrollment has surpassed 560,000 students² continuing the decades-long trend of increased enrollment. The overall increase in numbers is promising; however, despite increasing enrollment those who become engineers has yet to mirror national demographics.^{1,2,4}

Engineering is a profession, which has recruited, retained, and rewarded a limited demographic profile. Resulting in a stereotypical image of an engineer; masculine, white, technically competent, and socially awkward. By continuing to use the same limited demographic profile, engineering is crippling its intellectual potential. The challenges engineering faces require solutions that are both technically and culturally responsive and are beyond what the traditional group alone can achieve.^{5,6} The diversification of engineering creates opportunities for social and economic advancement. Increasing the diversity of the students becoming engineers has a variety of tangible benefits including; improved solutions^{7,8}, improving communication skills⁹, increased creativity¹⁰, solutions that are culturally responsible¹¹, and an expectation to have diverse peers.¹² The need for more engineers is beyond what can be provided from the conventional population; thus, there is a need to expand the definition of who can be an engineer.

The President’s Council of Advisors on Science and Technology reported the “academic culture in STEM fields is sometimes not welcoming or attuned to members of groups underrepresented in STEM fields.”¹ Overcoming the “chilly” climate of engineering,^{13,14} is one of the challenges facing the engineering community. Research has shown that meaningful social interactions have the potential to warm the climate, while simultaneously improving student outcomes. It has been reported, “the classroom is, for many students, the one place, perhaps only place, where they meet each other and the faculty.”¹⁵ Additionally, Tinto¹⁵ stated that if getting students engaged in their educational environment both academically and socially does not occur within the classroom, then it was unlikely to occur elsewhere, emphasizing the value and need to understand classroom interactions.

Several STEM education researchers have sought to understand how diverse students experience and self-organize within classroom environments.¹⁶⁻¹⁹ Typically these efforts concentrate on the nature of the interactions and the interpersonal/intergroup dynamics.^{14,20-23} Examination at this micro-level is vital to understanding how relationships are formed, but tends to ignore the larger social structures of an environment. Examining the interaction patterns (i.e., the social structure) of students creates an understanding of how individuals are included in developing communities,

“even a single time-slice of the social network of a class, which shows the social ties between the students, can reveal much about a student’s position in the network.”²⁴

Social network analysis (SNA) is a powerful tool for examining the arrangement of relationships between students rather than the content/context of the relationships, by providing a set of tools to evaluate and characterize the social structure of an environment. Allowing the interaction patterns of the environment to be scrutinized, potentially revealing the hidden social structure of the environment. SNA has been used in a variety of STEM environments ranging from understanding how teaching resources and pedagogies are spread and utilized,^{9,25–27} perceptions of other team member interactions,²⁴ retention and persistence issues,^{28,29} and to understand the social process of ethical design.³⁰ Given the body of literature demonstrating the importance of social interactions we propose that diverse individuals should be dispersed throughout the network to encourage meaningful interactions with a wide variety of people, thus warming the climate of engineering. As engineering educators, we want to avoid groups with high homophily and relatively few connections to the overall network (i.e., isolated homogenous groups). Homophily represents a bias that leads similar people to associate more frequently than is expected and “limits people's social worlds in a way that has powerful implications for the information they receive, the attitudes they form, and the interactions they experience.”³¹

To maximize the benefits of diversity, a first step is to ensure that diverse students are being integrated throughout the social structure. There is a myriad of recent work illustrating the power and insight gained from SNA. While there is an abundance of literature about the use of SNA, very little was found that provided a comprehensive discussion on the development and implementation of a self-reported survey to collect the rich data required for SNA. We address this shortage and the noted difficulties³² in collecting representative self-reported SNA data through discussing the development of a self-report survey for use in a large multi-section first-year engineering design courses. Through discussing our use of SNA, including iterative development and a brief example of how results can shed light on the social-structural integration of diverse students, we serve to further integrate SNA into the toolkit of engineering education researchers. Social-structural integration is used to understand how individuals who possess diverse characteristics are incorporated into the social networks of a large-enrollment multi-section engineering design course. The overarching goal of developing this instrument is to not only examine student social networks broadly but, also to comprehend the inclusiveness of the engineering community through understanding how diverse individuals are incorporated into the social structures of engineering education.

Social Interactions and Diversity

Understanding how students associate and accommodate diverse individuals is vital to creating long lasting change and warming of the engineering climate. It has been reported^{12,33} that exposure to cultural diversity has the potential to increase openness to diversity and an increase in cognitive skills. A multi-institutional study³⁴, found that students who had cross-race socialization had higher levels of academic development and greater satisfaction with college. Following this trend, Antonio and colleagues¹² discovered that diversity in a student’s friendship network acts to define their social norms thus, creating an increased expectation of diversity. These findings suggest that a shift in the demographic makeup of engineering not only supports

creating a more equitable experience, it also improves the development and academic performance of the students.

“Information and decision-making theories predict that diversity leads to increased cognitive processing, careful analysis, and better use of information. The result is enhanced creativity and problem solving (p. 733).”⁸ Despite these potential benefits it has been noted that individuals are more likely to work with individuals who are similar to them.^{35,36} The tendency to seek out homogeneous peers comes from the fact that these individuals possess a set of shared norms that form the foundation of interaction.

Student and professional groups as well as institutional initiatives have emerged to support diverse students, yet these resources may serve to divide students further. These programs often “spotlight” the differences between the groups and have the potential to create or reinforce biases.³⁷ To overcome the limitations that have arisen from these programs and the tendency to associate with similar others, solutions that socially integrate diverse populations need to be developed. By analyzing the patterns of interactions that occur in engineering, we can begin to understand how diverse individuals are incorporated into the social structure. “Social network analysis holds significant promise for the description and analysis of student learning communities, and, therefore, has a potential impact on methods of supporting students’ participation, retention and persistence (p. 8).”¹⁶

Social Network Analysis

Student interactions are a fundamental aspect of the academic experience, that can affect both behavior and success. SNA is a tool that can provide insight on group interactions, cohesion, engagement levels of participants, and strength and direction of interactions.¹⁹ Providing teachers and researchers a quick way to evaluate the inclusiveness of the environment. An advantage of SNA is its ability to generate a visual representation of all the connections that occur within the environment. These sociograms are a “great value for detecting different collaborative patterns that emerge from classroom based activities.”³⁸ Using SNA in a physics learning community, Brewe and colleagues discovered that “more interactions are associated with higher conceptual learning gains, (p. 377)”¹⁸ as well as a collaborative environment that was conducive to a more equitable learning experience.³⁹

A social network is comprised of actors (also called nodes), which refer to the entities that form the relationships; in our study, these are the students. The interactions between students create ties (also called edges) and the organization of these ties is at the heart of SNA.^{40,41} Characteristics can be assigned to both the nodes (e.g., race, sex, gender, etc.) and ties (e.g., weights and directionality); attributes that allow inspection of how various characteristics are integrated into the network. The level of an actor’s connectedness is quantified by degree, which is a count of all the connections to other nodes within the network. Degree accommodates directionality, which is determined by whether the actor initiated (*out-degree*) or was the recipient (*in-degree*) of the connection. Out-degree is associated with sociability, as these students seek out others. A student that is often sought out by other members of the network is considered popular, and will have an increased in-degree. These are both measures of the individual and are not influenced by interactions that occur outside of their domain. When

describing the level of connectedness of the overall network, density is often used. Density is determined either by the ratio of isolated to connected actors or by the proportion of connections that are present to the total possible connections. Network density is a popular, simple measure to estimate the network's inclusiveness. This alone cannot adequately describe how a network includes diversity. An inclusive environment should be such that the number of isolated nodes is minimized, the degree distributions (both in and out) do not have excessive non-normality. In this manner, both the behaviors of the overall network and the students' network are considered.

The results presented below demonstrate the iterative development of an instrument to measure social networks in a large-enrollment, multi-section first-year engineering courses. As such, we will discuss the social network instrument and modifications to the instrument, population and environment in which the survey was administered; and results and limitations of the survey for each study. We will then discuss the finalized instrument and considerations for implementation of the instrument in other studies.

Study 1 – Feasibility Testing: Can We Measure Student Interactions?

To understand how diverse students were situated within the social networks of large introductory engineering design courses, we deployed a previously established SNA instrument in a first-year first-semester engineering design course at a large public, land-grant institution. The course was structured as an introduction to engineering design and students were required to work in teams to solve a variety of design tasks (e.g., designing a net-zero energy house for habitat for humanity). Instruments previously established by Brewe and colleagues¹⁶ for use in introductory physics laboratories were adapted for use. In brief, students were asked “Who do you work with on engineering assignments (i.e., homework, projects, etc.)? Please list all.” Of the 860 students enrolled in the class, 725 responded to the survey resulting in a response rate of 84%. This SNA question was administered as part of larger, pen and paper survey of student attitudes towards diversity during the final weeks of the semester.

Data was manually compiled into an edge list, a paired list describing all the connections within the network. During the initial exploration of the data, it appeared that students only provided a few of the numerous connections that we believed occurred within the collaborative environment. This hypothesis was based on field observations and previous experience within the classroom environment. Reviewing the out-degree distribution (Table 1) further suggested that students only identified a small portion of the connections that were observed in the course. The predominate number of ties students provided only identified their assigned team members (i.e., students were assigned to work in teams of four over the semester). To confirm this hypothesis a subset of 107 (15%) responses were examined in greater detail; this sample size is comparable with other studies and allowed for a greater level of visual detail in the resulting sociogram (Figure 1). The network map confirmed the hypothesis that when students did respond, they predominately only identified the other students in their assigned team. As is observed from the Figure 1, the overall network is comprised of many small groups (i.e., teams). However, the more intricate set of interactions in the sociogram confirms that it is possible to capture a complex and representative view of the students' social networks. These findings confirmed that it is possible to implement SNA in a large team-based engineering design course,

while simultaneously demonstrated a need to develop a method to collect more representative data of the social connections occurring in this team-based course.

Table 1. Out-degree distribution for the first survey administration

Number of ties	N	% of responses
0	139	16.2
1-2	47	5.5
3-4*	622	72.3
5-10	48	5.6
10+	4	0.5
Total	860	100.0
* "My group" responses included		

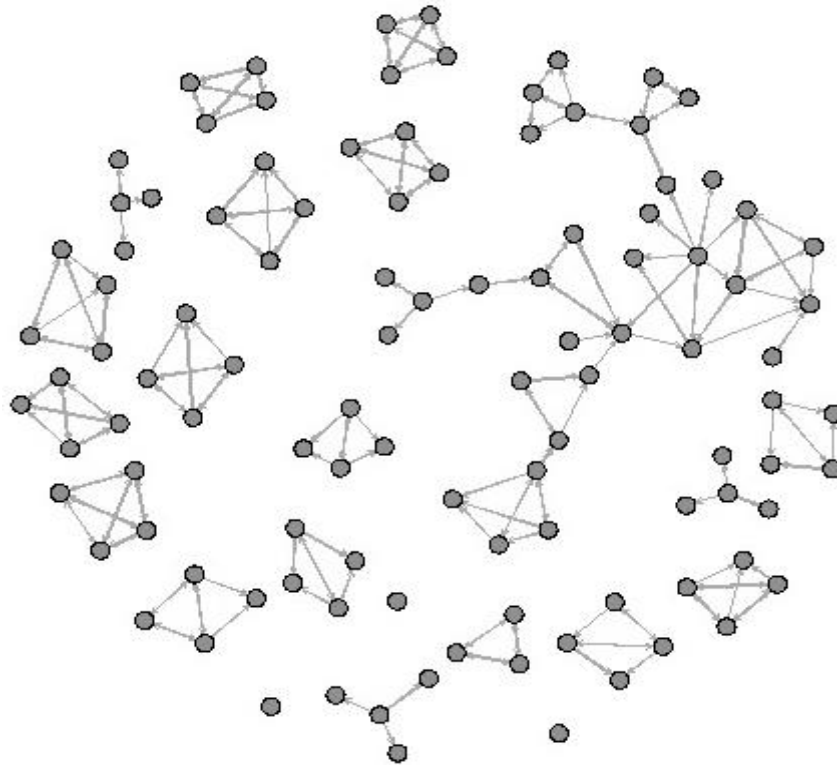


Figure 1. Sociogram from a subset of initial social networking data ($n = 107$) suggesting that students predominantly mentioned their group members.

Field Expert Consultation and Internal Piloting

In redeveloping the survey, we set out to capture a better representation of the student's social networks, while minimizing survey fatigue. Early in the development process, we decided to use an online platform for data collection. This change would allow for the tool to be easily deployed to a large population and greatly increase the ease of preparing data for analysis. After consulting with methodological experts, Dr. Eric Brewe, we confirmed that user errors (e.g., misspelled names, using nicknames) significantly increased the difficulty of data preparation. In addition to

the obstacles that an open-ended question presented for data manipulations, we acknowledged that asking a participant to recall all their interactions was tedious and could result in unnecessary survey burden. Due to these factors, we decided to provide a list of people that they would most likely interact with, using course enrollment records, a similar method was used by Simon and colleagues,²⁴ we however did not provide photographs along with the list of names. Specifically, the survey was pre-populated with the names of each student that was enrolled in the same section as the student taking the survey. The pre-populated survey required the participant to indicate with whom and the frequency of interactions that occurred, an example of the survey instrument is provided in Appendix A. To keep the versatility of the survey, free-response questions are included at the end of the survey, asking the students to list anyone else with whom they had interacted.

The initial piloting of the instrument was done within two collaborative research groups located at different institutions. These groups have an established history of collaboration, share similar research objectives, and were currently collaborating for the larger project for which social networking was being utilized. The digital survey listed the names of the 22 members of the research groups (e.g., students, faculty, post-doc researchers). Included at the end of the survey was a space for feedback. While this population does not match the characteristics of the target population, we proceeded expecting a high response rate and constructive feedback.

Two key results for this study were 1) the need to provide a clear explanation of how the list of names was generated and 2) considerations of participant privacy. Wording for the survey header and information letters were refined to include a more detailed discussion of how the names were generated. This change was the simpler of the two issues to address. Consideration for participant's rights was more challenging, stemming from the inability to completely opt out of the research project. For example, it is possible to indicate in the free response fields an individual that was not participating or someone that had chosen to opt out of the project. Once this significant concern was brought to our attention, the local institutional review board (IRB) office was consulted. Results of the consultation required amending the student information letter to include a discussion of their potential for inclusion even when removed from the survey by the research team. The subsequent updates to the survey were approved by the local IRB board.

Study 2 - Deployment and Redesign: A Pilot

To verify that the newly developed tool would perform as expected, the survey was administered in two summer physics laboratory-based classes for engineering and science majors. The classes consisted of 21 and 24 students, and enrollment records indicated that greater than 90% of the students enrolled were declared as engineering majors. The course required students to work with a partner as they completed experiments and assignments. This sample and the teaming environment reflected several similarities to the first-year engineering programs for which this instrument was intended. An email introducing and containing a link to the online survey was sent to all students during the final days of the course. Response rates were extremely low ($\approx 7\%$) due to the timing of the survey and lack of in-class announcements. However, the few results that were obtained demonstrated that students would identify others outside of their teams and even their sections, through use of the free-response questions.

The final version of the survey consisted of a cover letter describing the purpose of the research and data collection, a prompt asking the students to indicate all students that they interacted with (including a brief description of how we defined an interaction), a list of all students enrolled in the participants class (with the ability to indicate the frequency they interacted), and two free response question asking if there were any additional students that they had interacted with (both in and out of their class; see Appendix A). Together these changes allowed the students to quickly identify other students in their class that they interacted with and still provided the flexibility for the participant to mention others with whom they had interacted with. The results of the pilot suggested that the new survey is an improvement over the previously administered survey, and could provide the level of detail required to study the social structures of a large multi-section engineering design course.

Study 3 – Using Social Network Analysis in a Large-Enrollment Multi-Section Introductory Engineering Design Course

Open Engineering Lab

The social network data collection survey was developed for use in a large first-year, first-semester multi-section introductory engineering design course with an initial enrollment of 673. Consisting of mostly first semester engineering students, approximately 90% of all incoming students intending on majoring in engineering were enrolled. The course was structured such that students attended one of two large lectures and a laboratory session each week. In addition to the formal course meetings the students were highly encouraged to meet at least weekly outside of the classroom with their design teams. The main lectures had approximately 350 students; while, each of the 24 laboratory sections had a maximum of 32 students. The laboratory sections meet in a classroom located in the back of an open engineering lab (OEL) that was available to students from 9 am – 9 pm seven days per week. The OEL is a large open work space where students are encouraged to work on their semester-long design project as well as to use it as a study space. The OEL was open to all engineering students but was primarily used by students in the first-year course. Typically, between 30 and 100 students as well as 3-8 members of the teaching staff (three lectures, 13 graduate teaching assistants, and 11 undergrad teaching assistants) were in the OEL at any one time. This space was known to be a collaborative environment, and often students were observed working on other courses and forming study groups. Due to this open collaborative environment, it was likely that students would interact with others that were not in their laboratory sessions.

This active and open environment created and encouraged a complex collaborative learning atmosphere for students. In the OEL students would interact with students in the same introductory course, other students (in different engineering courses or other majors), undergraduate teaching assistants, graduate (both doctoral and masters) teaching assistants, and faculty. The range of interactions in the OEL created both formal (related to course material) and informal (social) opportunities for interaction.

Students were placed into diverse teams of four or five using the Comprehensive Assessment of Team Member Effectiveness (CATME) team formation tool.⁴² Team assignments considered

out-of-class schedules (this consideration of other obligations was to ensure all members had similar availability to meet outside of regular class schedule), diverse background (e.g., race, ethnicity, gender), and prior academic performance using a self-report questionnaire in the CATME team formation tool in the second week of classes. Team construction ensured that members of underrepresented populations in engineering were not an isolated minority but also that the teams had heterogeneity in composition. When possible, attempts were made to disperse diverse individuals throughout the class section.

Administration of the SNA Survey

The SNA survey was administered three times over the course of the sixteen-week class (weeks 4, 9 and 14). Students were informed of the survey, through in class lecture announcements (both main lectures and in lab sections), course wide email announcements, and the link to the survey was included alongside regularly scheduled assignments. Participation incentives included extra credit and entry into a random drawing. Students that participated received .02% extra credit for survey they completed, additional extra credit opportunities were provided for those who could not participate (e.g., were younger than 18). For each administration of the survey students who participated were entered a random drawing for a \$10 gift card (awarded to 10% of the respondents). The first SNA survey had a response rate of 75% ($n = 508$), while the final two surveys had approximately half of the students respond ($n = 338$ and $n = 304$, respectively). On average, students took five minutes to complete the survey and greater than 80% of the students that started the survey completed it. To understand how student social networks were formed, the first survey was administered during week four of the semester. This timing corresponds to one week after the teams had been assigned, and a month after most students had started their engineering degree, providing insight into how rapidly student social and academic peer networks develop. The data collected will allow longitudinal analysis, providing insight into the formation of students' social structures. This analysis is beyond the scope of this paper, and will be addressed in future work.

Results of the Survey Administration

The first step of analysis was to create a course wide sociogram to determine the level of detail that the new survey captured. Data analysis was done in R using the `sna`⁴³ and `igraph`⁴⁴ packages. As shown in Figure 2, the sociogram revealed a variety of network structures including; isolated nodes, isolated teams, small clusters of loosely connected teams, highly connected laboratory sections and a sprawling network of interactions that create bridges between several of the sections. The success of the new tool is evident when Figures 1 and 2 are compared. Based on the intricacy of ties present in Figure 2, we concluded that students did connect with peers outside of their assigned teams. We also observed that within the unique laboratory sections, students tended to interact together forming small communities within the overall population. The observation of the different network structures demonstrated the ability to capture interactions of individuals and provided insights into how intertwined the different laboratory sections are.

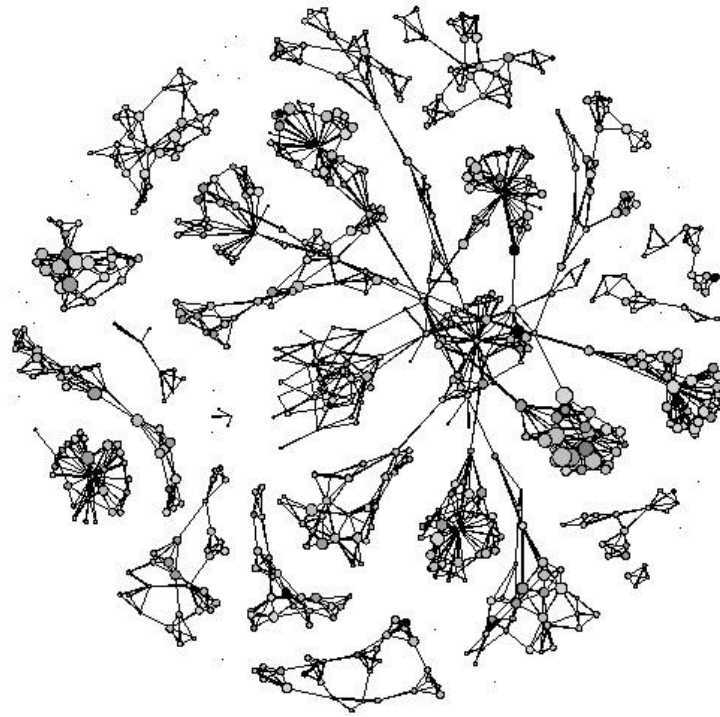


Figure 2. Sociogram of the entire social network as recorded with the newly developed SNA survey, data collected approximately 4 weeks into a 16-week course.

A sub-sample was selected to display the high-level of detail that was recorded relating to student interactions. Three consecutive sections were chosen for further examination. The choice to use three sections was done so that the sample size compared relatively well with the initial study run (93 and 107, respectively), and to several previous studies^{16,19,39}. A laboratory section was selected at random, and then two consecutive sections were included. It is believed that this selection process would likely have ties occurring between the different sections since they were offered in sequential order throughout the day. The sociogram for this subset of data is shown in Figure 3.

Students' self-reported demographic information was collected during the CATME team builder process, these self-reported attributes were included as nodal characteristics. Using SNA, we set out to understand how the different sexes are incorporated into the social structure. Sex is used to describe the male/female option provided in the CATME survey, and does not reflect the more inclusive measures of gender identity³⁶ that will be examined in future work. The figure indicates that students did not cluster based on their sex, i.e., there are not large uniform clusters of females. While these results show that individuals do not cluster exclusively by sex, it does not explain why this may occur. Ideally, students are seeking out diverse viewpoints in engineering, but it is possible that the numbers of females are low enough and spread out enough between sections that they struggle to form single-sex networks.

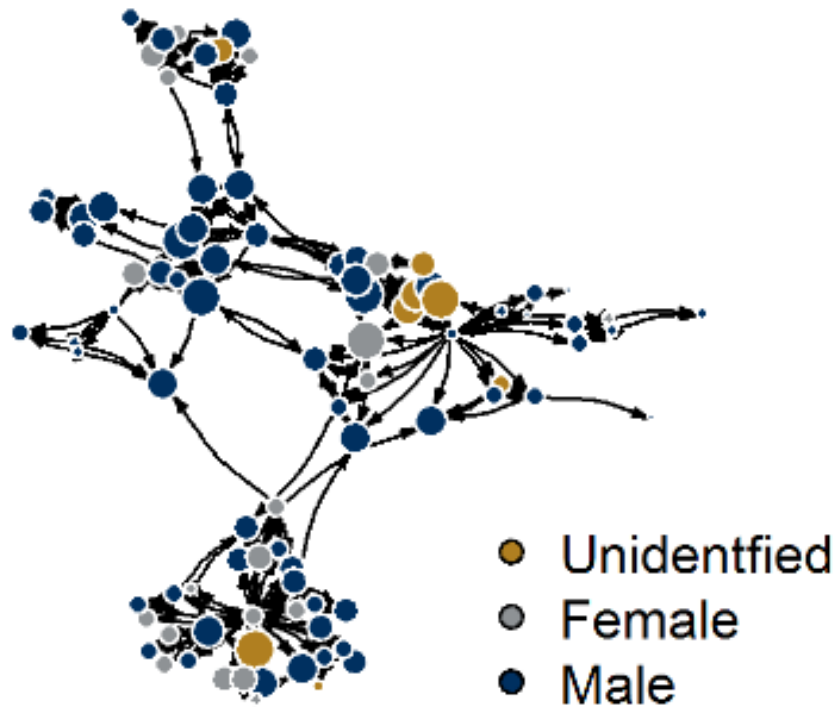


Figure 3. Sociogram of sub-sample (three consecutive laboratory sections) illustrating how the different sexes are incorporated into the social structure.

In addition to including the sex of each node, in-degree values were used to scale the size of each node. In-degree was used with the intention to understand the inclusiveness of the network and provides insight into who is sought out by whom and is a result of network behavior rather than participant response patterns.

A relatively equal distribution of nodal size is observed with in-degree values ranging from 1.0 to 6.0 with a mean value of 3.6 (median = 4.0; standard deviation = 1.2). An interesting observation is the cluster of nodes on the bottom of Figure 3, similar behavior is observed in the top-left cluster as well, the clusters are centered around a very small node (nodal size is based on in-degree values). This suggests that the most central person to the network was also among the least sought. In other words, this central person was not viewed as popular by their peers but identified numerous individuals on their SNA survey. While we cannot confirm the social behaviors of this node, the results of the data indicate that they are among the most structurally important nodes to the network.

To further explore these observations, a community detection algorithm was utilized. The method uses betweenness centrality (a measure that takes into account the shortest path between all nodes within the network), to detect communities of nodes where the average distance between them is reduced.^{40,41,43,45} The results are shown in Figure 4, allowing for the hidden community structure to be highlighted. From this figure, we observed that there were two large communities within these three sections as indicated by the shaded regions with high numbers of participants (top and bottom left of the figure). Further examination of the data indicated that

these two communities were two course sections. The remaining smaller shaded regions represent engineering teams that formed their own communities within the third section.

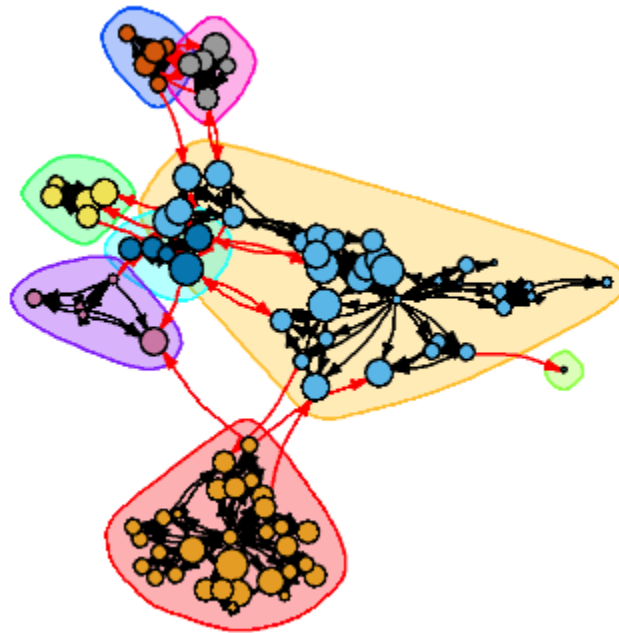


Figure 4. Community detection using betweenness centrality, two of the three section appear as intact communities due to a single node with high out-degree. Ties are color coded to indicate ties that bridge formal section boundaries (red) and those that do not.

In each of the large communities, there is a central node with an above average number of outward ties and a small number of in-bound ties as shown by the small node size and numerous tie surrounding the node. The effect of this nodes is to connect the course section, which is observed through the community detection process. Illustrating the influence that a single person can have on developing a community structure.

Discussion and Implications for Research

Social network analysis can reveal how diverse individuals are dispersed throughout the social structure of an environment. The interactions between diverse individuals have great potential to affect student development both academically and socially. First-year engineering environments often consist of large-enrollment courses with multiple sections in which students interact across sections. The interaction of students across these formal boundaries makes a precise assessment of their complete social network challenging. Building upon previous work, our study in an OEL represents a substantial leap in scale, size, and complexity compared to the environments where SNA has been previously administered^{16,19,24,30,46} but mirrors the environments of many first-year engineering programs.

Our SNA instrument is an improved tool for capturing the complexity of student social networks. Founded on previous SNA instruments,^{16,18,39} it substantially improves measuring the intricacies of student social connections. Deploying an existing instrument was cumbersome for both

participants and practitioners. Asking the participant to recall their interactions resulted in a low response rate and reduced number reported ties when compared to classroom observations. These issues, coupled with the difficulty of deciphering the results (e.g., spelling errors and multiple aliases) created additional hurdles for data analysis. Our new instrument overcomes these limitations and allows for careful exploration of the social network. This new mechanism for collecting SNA data opens the possibilities for studies at programmatic, departmental, or multi-section courses to understand the ways in which students interact across the boundaries of a section, course, advisor, or major.

We have presented an initial analysis of the results of this new instrument in Figures 3 and 4. These figures illustrate how different sexes are integrated into the social networks of a first-year engineering course. This work begins to explore the ways in which underrepresented students are included in these networks. Preliminary results indicate that the different sexes in an engineering classrooms share similar ties to others in the network. Indicating that the perceived chilly climate in engineering¹³ may not manifest from a lack of interaction, but rather the *nature of the interaction* between students. Further analysis is ongoing to confirm this trend in the rest of the data and to explore how students experience working in diverse teams. Additionally, these preliminary results demonstrate the versatility and level of detail that is possible to collect using our new tool. While we have chosen to demonstrate, the adaptability using sex, this tool and method have the capabilities to accommodate an extensive array of characteristics including traditional demographic markers (e.g., race, ethnicity, gender, etc.) as well as latent characteristics (e.g., attitudinal survey data, academic performance). Knowledge of how these students and their characteristics are incorporated into the social structure can potentially lead to cultivating their belongingness or the warming of the climate within engineering. Further analysis will explore the experiences of underrepresented students in-depth, including but not limited to women in engineering.

Limitations and Recommendations

Student social networks are ever evolving, as students develop and dissolve “meaningful” connections between one another. The use of a self-report survey likely does not capture all the interactions that are occurring in the OEL or the evolution of student social networks. Completely capturing students’ social interaction requires a significant shift in approach and measurement that is beyond the scope of this work. Future work will utilize the longitudinal data collected to examine how the student networks evolve during a semester long engineering design course. In addition, a comprehensive examination of how diverse students are incorporated into the social structure, this will include more inclusive measures of traditional demographics (e.g., the disaggregation of gender and sex) as well as mapping latent characteristics illuminated from an additional survey.

The efforts described here demonstrate the application of SNA; however, careful interpretation of the results is crucial. SNA provides a valuable and powerful quantitative description of student interactions. For example, if a student reports a high out-degree that corresponds to high sociability, we cannot determine if this outcome is a result of their social behaviors, a response pattern due to their interpretation of the survey prompt or disruptive behavior.

For researchers seeking to implement the instrument in this study the following concerns need to be addressed prior to implementation: 1) boundaries of the environment to be studied; 2) transparency on how the survey was populated; and 3) participant partition, an inability to remove themselves from the study and the inclusion of non-informed students. These three concerns are discussed below with recommendations learned from our research.

Network Boundaries

The decision of what interactions are of interest and what environment the interactions occur in is particularly important. Social networks have the ability to ascend formal boundaries of a classroom, department, college, or geographic region.^{32,40,41,47–49} Determining the boundary conditions is a crucial first step, in implementing SNA. There are natural choices in engineering education such as a class or classroom. However as depicted here these formal boundaries do not prevent interactions from occurring. Along with determining the area of interest, consideration of how to deal with connections that cross these boundaries needs to be considered in the implementation of the instrument. These interactions are potential avenues for different information to infiltrate the network.

Transparency

During the analysis and debriefing of our second pilot study, there were reports of anxiety and reluctance to provide information regarding a participant's social ties. We discovered that the convenience having a pre-populated list of student's names could create concerns regarding their privacy and the privacy of others. To reduce these concerns, transparency on how the names were populated is essential. We overcame this obstacle through, in person introductions describing the nature of the data collection, including the process that name list was generated (both on the cover page and in the question prompt), statements about confidentiality and describing the process that would be used to anonymize the data.

Participant Participation

The nature of the data collected presents unique considerations that traditional quantitative surveys avoid, students cannot be removed from data collection. However, the inability to be removed does not mean that all students actively participate in the project. This nuanced and particularly important clarification is rooted in the fact we cannot control how the students' respond. The inclusion of a free-response question provides an opportunity to identify people that choose to opt out as well individuals that were unaware of the research. Unlike traditional surveys that seek to understand a student's behavior and/or beliefs, social networking seeks to understand the environment surrounding the student. The survey asks the students to identify the people that they have interacted with and provides a listing of all the students in their laboratory section. The inclusion of a free-response question provides the opportunity for any students to be identified even if they were formally removed from the instrument. Names not displayed in the prepopulated list of the survey would identify this individual to their peers thus, violating their rights as a participant. These issues create tensions between collecting meaningful data and protecting the participant's rights.

To ensure compliance we consulted the local IRB office, this consultation resulted in the need to increase the transparency of the project, provide multiple avenues to inform the students of their participation and rights. Statements informing all students of their inclusion in the research were included in the course syllabus, informing them that by enrolling in the course they were allowing consent of the research project. Despite consent for inclusion in the research project, this process did not guarantee their participation in the project. Opportunities were available for students to opt out of providing information regarding their social networks but the notification informed them there was a potential they could be included. All surveys included a copy of the project cover letter (with multiple pieces of contact information to allow students to opt out) and a member of the research team notified all students of the project and their potential inclusion on the first day of class. The possibility of including non-informed and those that choose to opt out requires that all data to be immediately anonymized to ensure that their rights and privacy were protected.

Conclusions

This SNA instrument provides rich detailed relational data to understand patterns of interactions and how members of diverse populations are integrated into the social structures of a large-enrollment, multi-section first-year engineering design course. Our instrument can capture a better representation of the intertwined labyrinth of social interactions that occur within an open engineering space. Understanding the structures of student interactions and how diversity is dispersed throughout the network can shed light on the inclusiveness of the environment and starts to grasp the complexity of student social ties. This information can provide practitioners the information required to understand how an engineering community includes members of underrepresented groups leading to the warming of the climate and better representation of diverse populations.

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Appendix A - Newly developed survey instrument

We have provided a copy of the survey instrument that was developed as part of this project. *Please note all names for this example are fabricated and are not meant to reflect or represent any know peoples.* The survey used logic to provide a focused list of names.

Consent Principal Investigator: *PI Affiliation and contact information*

Description of the research and your participation You are invited to participate in a research study assessing your attitudes and social connections in engineering. We are studying these factors through the use of surveys, observations, and interviews. We will be studying the relationships, if any, to other student information, namely predicted GPA, SAT scores, gender, race/ethnicity, high school, course grades, and current GPA. These data will be collected through various offices on campus, including the Dean's office in the College of Engineering, the Office of Admissions, and the Office of Institutional Analysis.

Your participation will involve completing a survey. You may also be invited to participate in further studies, including interviews. These would occur no more than twice

per semester until you graduate. Your academic record data will be collected through graduation.

Risks and discomforts There are no known risks associated with this research.

Potential benefits Your information may benefit future students by helping us make engineering teaming experiences more effective at *institution of study* and nationally. In addition, this research will be disseminated so that students and faculty at other institutions may benefit as well. Participation in the survey portion of this work will enter you into a raffle for a \$10 gift card during each survey period. If selected for participation in interviews you will be given a \$25 gift per interview or observation completed.

Protection of confidentiality We will do everything we can to protect your privacy. Your name will not be recorded in any way in the compiled survey and course work data. Information used to generate the following survey were pulled from course records. All information will be de-identified prior to dissemination. Your responses will be marked with a code. Only the Principal Investigator will have the key which links your identity to that code, and this key will be destroyed as soon as all data have been collected and compiled. Your identity will not be revealed in any publication that might result from this study. You will not be personally identified in any reports or publications that may result from this study. The researchers, the Department of Health and Human Service (HHS), and the *institution of study* Social Behavioral Institutional Review Board may look at your study records.

Voluntary participation Although completion of the survey may be for extra credit, information from the survey and education records for research purposes is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. Additionally, your decision whether or not to participate in the research will not affect your course grade in any way.

Exclusion Requirements Participants must be at least eighteen years of age to be eligible to participate.

Contact information If you have any questions or concerns about this study or if any problems arise, please contact *PI* at *office phone number*. If you have any questions or concerns about your rights as a research participant, please contact the *University IRB office contact information*

Students were required to acknowledge the cover letter before proceeding by clicking on next page button at the bottom of the screen. On the following screen the students were asked to choose their section from a drop-down list.

Section ID Please select your ENGR lab section:

- ☐ Section 1101 (Monday at 9AM) (1101)
- ☐ Section 1102 (Tuesday at 9AM) (1102)
- ☐ Section 1103 (Wednesday at 9AM) (1103)
- ☐ Section 1104 (Thursday at 9AM) (1104)
- ☐ Section 1105 (Friday at 9AM) (1105)
- ☐ Section 1106 (Monday at 10:30AM) (1106)
- ☐ Section 1107 (Tuesday at 10:30AM) (1107)
- ☐ Section 1108 (Wednesday at 10:30AM) (1108)
- ☐ Section 1109 (Thursday at 10:30AM) (1109)
- ☐ Section 1110 (Friday at 10:30AM) (1110)
- ☐ Section 1111 (Monday at 12PM) (1111)
- ☐ Section 1112 (Tuesday at 12PM) (1112)
- ☐ Section 1201 (Monday at 1:30PM) (1201)
- ☐ Section 1202 (Tuesday at 1:30PM) (1202)
- ☐ Section 1203 (Wednesday at 1:30PM) (1203)
- ☐ Section 1204 (Thursday at 1:30PM) (1204)
- ☐ Section 1205 (Friday at 1:30PM) (1205)
- ☐ Section 1206 (Monday at 3PM) (1206)
- ☐ Section 1207 (Tuesday at 3PM) (1207)
- ☐ Section 1208 (Wednesday at 3PM) (1208)
- ☐ Section 1209 (Thursday at 3PM) (1209)
- ☐ Section 1210 (Friday at 3PM) (1210)
- ☐ Section 1211 (Tuesday at 4:30PM) (1211)
- ☐ Section 1212 (Thursday at 4:30PM) (1212)

The survey used logic flow, to determine proceeding questions. After the students identified their class section, they had to click a next button, which brought up another screen asking the students to identify themselves.

Display This Question:

If Please select your ENGR lab section: Section 1101 (Monday at 9AM) Is Selected

Me1101 Which student in Section 1101 are you?

- ☐ Clarence Brock
- ☐ Lucille Bowen
- ☐ Joshua Ramierez
- ☐ Kerry Collier
- ☐ Nora Richards
- ☐ Clinton Perry
- ☐ Amos Patterson
- ☐ Manuel Myers
- ☐ Molly Parker
- ☐ Marta Gross

The student was required to click a next button on the bottom of the screen. This would bring them to the main listing of names, using survey logic their name was removed from the list of available contacts. On the following page the students were presented a table where they could indicate which student they had interacted with. Proceeding the table were two free-response question asking for any other contacts that they had regarding completion of the *Engineering Design Course*.

Display This Question:

If Please select your ENGR lab section: Section 1101 (Monday at 9AM) Is Selected

Carry Forward Unselected Choices from "Which student in Section 1101 are you?"

We are interested in your engineering social network for *Engineering Design Course*. Your social network includes people that you interact with to complete *Engineering Design Course* tasks. This network can include your team members, other students in the same lab section, students in other lab sections, or peers that you seek out for additional help. Your engineering social network includes those you work directly with or alongside. Interactions include, but are not limited to, studying, solving problems, lab work, project development, or discussions of engineering related topics.

Please indicate how many days a week you interact with each student in your lab section.

	I did not work with this person	1-2 days	3-5 days	More than 5 days
Clarence Brock	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lucille Bowen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Joshua Ramirez	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Kerry Collier	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nora Richards	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Clinton Perry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Amos Patterson	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Manuel Myers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Molly Parker	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Marta Gross	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please identify any additional *Engineering Design Course* students that you interacted with. (First and Last Name)

Please identify any additional peers that you interacted with for *Engineering Design Course* tasks. (First and Last Name)
