

Using Social Network Analysis as a Tool for Improving Teaching Effectiveness

Dylan Dittrich-Reed, Clemson University, United States
Andrew Kardohely, Clemson University, United States

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Abstract

Social network analysis (SNA) is an excellent observational tool for understanding community formation in the classroom. Students engaged in the classroom community might be more likely to persist in a major or discipline. Classroom community structure, therefore, could be an indication of effective teaching practices that help retain students. However, SNA is largely untested as a tool to identify disengaged students who could benefit from instructor intervention. A pilot study of undergraduates in biological sciences laboratory classes at a public, southeastern, land-grant university demonstrated a statistically significant negative relationship between self-reported likelihood of changing disciplines and formation of ties with other students. We propose that SNA could allow instructors to identify disengaged students that are at risk of leaving their discipline and make recommendations for re-engaging such students.

Keywords: Social Network Analysis, Persistence, Classroom Community, STEM, Biological Sciences

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Introduction

Now more than ever there is a high demand for graduates prepared for STEM fields (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013). One way to meet that demand is to retain more undergraduates in STEM degree programs by providing them with the academic and social support networks they need to persist in their programs (Tinto, 1998). Social and academic support networks are often intertwined, but need to be considered individually (Ibarra & Andrews, 1993). Social support networks consist of individuals (*i.e.*, acquaintances, friends, family, mentors) that provide emotional support and advice, while academic support networks consist of individuals with whom one can exchange information and co-construct knowledge (Tomás-Miquel, Expósito-Langa, & Nicolau-Julíá, 2016).

At university, a student's social and academic support networks may overlap substantially and both are critical for academic success and persistence (Dawson, 2008). In one study, first-year undergraduates with more school-affiliated friends in their support networks (Skahill, 2002) were more likely to persist. Social/academic networks such as residential learning communities can also increase persistence (Brewer, Kramer, & Sawtelle, 2012) and increase performance (Jo, Kang, & Yoon, 2014). For example, physics students that were most active in their residential learning community were more likely to persist (Brewer et al., 2012). Fostering a sense of belonging in the classroom should therefore increase persistence and retention.

However, with increasing class sizes common at many universities, especially introductory courses in STEM degree programs, the task of creating a sense of community and forging connections among students might seem daunting. Time and effort spent developing student support networks must be spent efficiently. Therefore, we need a tool to measure the complex structure of student social and academic networks in order to determine the most effective teaching practices to provide students with the social and academic support they need.

Social network analysis is a methodology that can be used to extract valuable information from a complex web of student connections (Carolan, 2014; Luke, 2015). A network is the term used to describe the set of ties (social connections or academic interactions) between actors or nodes (individual students). Through social network analysis both an actor's position in the network and the overall structure of the network can be quantified. Social network analysis also encompasses the statistical methods necessary to analyze network data, which often does not meet the assumption of independence of data that must be met for many standard statistical tests (Carolan, 2014; Luke, 2015).

The purpose of this pilot study was to determine whether student centrality in a network predicts their self-reported likelihood of persisting in the sciences. An actor's position in a network can influence their access to resources as well as their behavior (Carolan, 2014). Students with low centrality might have limited access to the academic and social support of their peers and suffer a decreased sense of belonging or self-efficacy. Low-centrality students, therefore, might be more likely to consider

changing majors or disciplines. Social network analysis could be an effective tool for instructors to identify students at risk of leaving the major and intervene in time to increase retention in the sciences.

Methods

The participants in this pilot study were undergraduate students enrolled in a single introductory biology laboratory at a southeastern, land-grant university in the Spring of 2016 (N = 28). Students self-reported ties to other students via an in-class survey. The survey asked respondents to identify the students in their lab groups as well as those they “engage with, about course material, inside and outside of class.” Because students might be more likely to report academic ties with lab group members, regardless of the quality of the connection, these ties were used as a covariate in our analyses.

The survey also asked students how strongly they agreed or disagreed with the statement, “I feel confident I will pursue this discipline.” Due to limited variation in student responses and small sample size, responses to this persistence question were recoded. “Strongly agree” and “somewhat agree” were both coded as “likely to persist” and “somewhat disagree” as “unlikely to persist.” No students chose the response “strongly disagree.”

We used reported academic ties to create and visualize the network (Figure 1) in R (R Core Team, 2016) using the *statnet* package (Handcock, Hunter, Butts, Goodreau, & Morris, 2008). We used exponential random graph models (ERGM) to determine whether there was a relationship between self-reported likelihood of persistence in the biology discipline and the formation of academic ties between actors. ERGMs predict the probability of forming a tie between any two actors, conditional on the rest of the network (simulated from predictor and covariate estimates) (Luke, 2015).

We fit three ERGMs in R using the *ergm* package (Hunter, Handcock, Butts, Goodreau, & Morris, 2008) and compared AIC scores to determine the best fitting model. We fit a “null” ERGM without predictor or covariate (m0) for comparison. We then fit an ERGM that only included the covariate lab group ties (m1). Finally, we fit an ERGM representing our research hypothesis, which included persistence as a predictor and lab group ties as a covariate (m2).

Although an ERGM analysis can determine whether node attributes such as persistence influence the formation of ties, it does not provide a straightforward means of identifying the actors (*i.e.*, students) that are less likely to persist. Centrality is a broad term for an actor’s position within the network structure and is measured in different ways (Luke, 2015). Degree centrality is measured as the number of ties an actor forms directly with other actors and is generally interpreted as an actor’s activity in a network. Betweenness centrality measures the extent to which an actor is situated between and connects via ties pairs of other actors. Betweenness is interpreted as the degree to which an actor connects different cliques of actors within a network.

We tested for an association between student centrality and self-reported likelihood of persistence. Because individual centrality scores are interdependent, we performed a non-parametric comparison of the median centrality scores of students likely to persist and unlikely to persist in biology. Using parameter estimates from m1, we simulated 10,000 networks to estimate a null distribution of differences in median centrality between the two groups. We performed this test for both degree and betweenness centrality.

Results

All 28 students responded to the survey. 60.7% of respondents were female. 27 students were enrolled in one of four majors in the field of biology: Biological Sciences, Microbiology, Genetics, and Biochemistry. Only one student was enrolled in the non-biology, but still STEM major of Physics. As might be expected for a majors biology course, only 4 (14.3%) of respondents reported that they were unlikely to persist in biology.

The classroom network is visualized in Figure 1. The density of the directed academic network was 0.066. Network density is the ratio of observed ties to total possible ties. Degree centrality ranged from 0-8 with a median of 3.5 and interquartile range of 3. Betweenness centrality ranged from 0 to 20 with a median of 0.5 and interquartile range of 9.125.

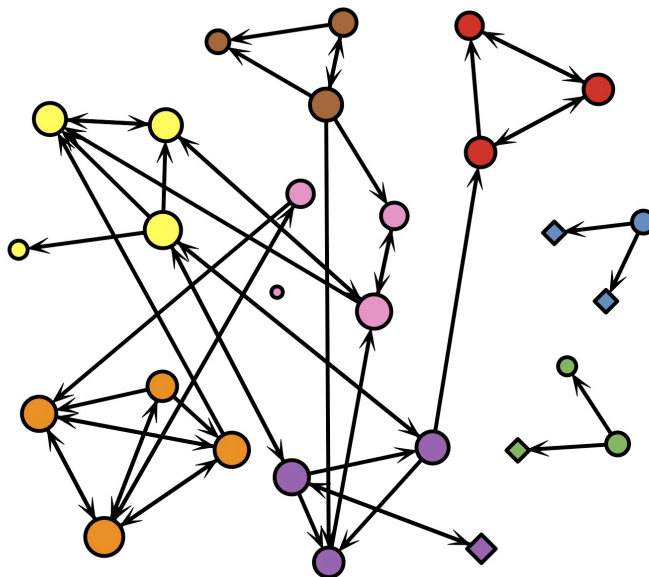


Figure 1: Directed network graph of the academic ties among students. Double-headed arrows indicate reciprocally reported academic ties. Node color indicates lab group; node size is proportional to degree centrality. Circular nodes represent students reporting they are likely to persist in biology; square nodes are those unlikely to persist in biology.

The ERGM with both self-reported likelihood of persistence as a predictor and lab group membership as a covariate (m2) was a substantially better fit to our data than other the simpler models based on both AIC and BIC scores (Table 1). The results of the ERGM analysis are displayed in Table 2. The covariate of lab group was important for determining the probability of two students forming an academic tie (log odds 3.807, $p < 0.001$). For example, the odds of two students likely to persist in biology forming an academic tie were 45.017 times greater for students in the same lab group to those in different lab groups (95% CI = [22.153, 91.481]).

| Model | Dependent Variables | Degrees of Freedom | AIC | BIC |
|-------|---------------------------------|--------------------|--------|--------|
| m0 | Edges | 1 | 370.22 | 374.85 |
| m1 | Edges + Lab group | 2 | 248.02 | 257.28 |
| m2 | Edges + Lab group + Persistence | 3 | 240.15 | 254.03 |

Table 1: Comparison of ERG models based on information criterion.

| Variable | Estimate ¹ | Std. Error | p-value |
|-------------|-----------------------|------------|----------|
| Edges | -6.3252 | 1.0093 | < 0.001* |
| Lab Group | 3.8070 | 0.3618 | < 0.001* |
| Persistence | 1.3828 | 0.5099 | 0.00684* |

Table 2: Summary of the ERG model fit for model m2. ¹Estimates are reported in log-odds. *Denotes statistical significance at the $\alpha=0.05$ level.

Self-reported likelihood of persistence was also important for predicting tie formation (1.383, $p < 0.01$). For example, for students in the same lab group, the odds of forming an academic tie between two students both of whom reported they were likely to persist were 3.986 times greater (95% CI = [1.467, 10.828]) than if one student was unlikely to persist and 15.888 times greater (95% CI = [2.153, 117.251]) than if both students were unlikely to persist.

Students reporting they were unlikely to persist in biology had a median degree centrality 3 units (*i.e.*, ties) lower than students likely to persist ($p = 0.0035$). There was no significant difference between median betweenness centrality for the two groups of students ($p = 0.7082$).

Conclusion

The ERGM and non-parametric analyses both provide evidence that network structure and self-reported likelihood of persistence are related to each other. Based on ERGM analysis, the odds of forming an academic tie increase by about 1.38 for students who plan to pursue biology. Consistent with Skahill's (Skahill, 2002) findings, students with more academic ties (greater degree centrality) reported they were more likely to

persist. It is unclear from this observational study whether students feel less likely to pursue biology because they failed to develop as many academic social connections in class as their peers, or the converse. If the development of academic social connections is important for retaining students in STEM degree programs, then instructors need to spend time and energy building a sense of classroom community fostering the trust that is necessary for academic ties (Jo et al., 2014).

The ERGM analysis also provided evidence that laboratory group membership increased the probability of academic ties. The odds of two students forming an academic tie in the classroom increase by about 3.81 for students in the same lab groups. Taken together with the observed close association between network structure and likelihood of persistence, we make the following teaching recommendations.

1. Increase the amount of group work to form social ties that may become academic ties.
2. Vary group membership to increase the density of the network.
3. Encourage student-to-student discussion of course content and concepts.
4. Learn student names in order to better facilitate student-to-student interactions.
5. Assess student social networks via repeated social network surveys.

Limitations

Our conclusions may not be generalizable for several reasons. First, this was a pilot study that only examined social network data from one laboratory course. The demography of this laboratory section was similar to that of the biology field majors at the university. However, undergraduates enrolled in an introductory biology course for biology majors are likely not representative of all STEM undergraduates. Second, student attitudes regarding persistence are subject to change and are influenced by many factors. Student responses might also reflect their pre-existing certainty in their academic and career goals rather than the influence of social connections in one particular class.

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Contact email: ddittri@g.clemson.edu