Using Social Network Analysis to Measure Student Collaboration in an Undergraduate Capstone Course[1]

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Abstract

Social network analysis offers a unique way for instructors to visualize collaboration and communication within a course and see relationships between individuals, groups, teams, or cliques. We used social network analysis to measure the growth of collaboration in the capstone AGEDS 450 Farm Management and Operation course at Iowa State University. With the strategic implementation of collaboratively intense assignments, student collaboration grew from the midpoint of the semester to the end of the semester. Overall density of the network increased from 0.25 at the midpoint to 0.35 at the end of the semester (40% growth). Each student's number of communication ties increased over the course of the semester to 17.2. Average geodesic distance between nodes decreased 11.7% from the midpoint to the end of the semester, resulting in an average pathway length of 1.66 to connect any two students; this improved communication efficiency in the course. No cutpoint existed at the midpoint or the end of semester, showing no risk of collapse in the network. The overall network became more complex, indicating a more inclusive collaborative environment. We recommend that instructors include structured activities that emphasize student collaboration to help develop strong information networks in other courses.

Introduction and Background

Capstone courses help students connect segmented academic theories with practical application to develop skills needed for entry into a career (Fairchild and Taylor, 2000). Although capstone course structure may vary by context, requisite learning activities should be included: projects, case studies or issue analysis, small-group work, oral communications, intensive writing and industry involvement (Crunkilton et al., 1997). With the inclusion of these activities, it is expected that students who complete a capstone course will develop or enhance the following skills: problem solving, decision making, critical thinking, collaboration and oral and written communication (Crunkilton et al., 1997).

The AGEDS 450 course is a capstone farm management and operation course required of undergraduate students majoring in agricultural studies at Iowa State University (ISU). The course is also available to other majors within the ISU College of Agriculture and Life Sciences. The course uses a working farm for which students must make real decisions. Because AGEDS 450 serves as a laboratory and provides an applied farm management experience (Trede et al., 1992), the course outcomes have been designed to provide students with the opportunity to apply skills in crop and livestock production, financial management, marketing and human relations that are needed in the daily operation and long-term strategic management of a production agriculture business.

Decision Making and Student Collaboration

Course outcomes for AGEDS 450 were determined by following recommendations of Crunkilton et al. (1997) and Andreasen (2004) to include the following capstone course components: problem solving, decision making, teamwork, critical thinking and communication. Decision making has been touted as an essential element in the education process (Andreasen, 2004) and is an important component in AGEDS 450. Trede et al. (1992) found that decision making ranked first among AGEDS 450 graduates in regards to appropriateness of instructional methods used in the course.

For the AGEDS 450 farm to operate productively, students are required to make various management decisions throughout the semester. Decisions include but are not limited to crop selection, fertilizer plans,

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grain marketing, equipment upgrades and technology implementation. Students work collaboratively through a structured course design. Each student is assigned to a committee on the basis of their interests and an application process at the beginning of the semester. There are eight committees reflecting various enterprise or management areas of the farm: buildings and grounds, crops, custom operations, finance, machinery, marketing, public relations and swine. The committees initiate the decision-making process, which affects the operation of the farm. Class participants elect a president, vice president and secretary who run official business meetings as a formal component of the course. Strategic changes or other decisions that affect the farm must be approved during the weekly business meeting. Using parliamentary procedure as an operating format, committees give weekly reports and recommendations to inform class members as they make decisions about operation of the AGEDS 450 farm.

Course instructors used several assignments during the second half of the semester which emphasized and required collaboration. Such assignments included:

State of the Farm: Students researched the history of the farm relative to their committee (e.g., swine, custom operations, or finance), provided an update on the current standing to their peers and determined short-term goals for the enterprise or management area of the farm over the course of the semester.

Strategic Issue: Students examined and researched a potential issue or opportunity to enhance long-term management or operation of the AGEDS 450 farm. Strategic issues *"focus on problems that impact all aspects of the farm operation from crop and swine production to equipment, land and labor management and related operational components"* (Paulsen, 2009). Designed with an interdisciplinary approach, the strategic issue assignment encouraged students to draw upon knowledge gained from previous coursework, internships, or personal experiences to think critically, problem solve and make decisions relevant to context-specific problems in the farm business.

These highly student-centered, team-oriented activities embody a learner-centered approach to problem solving and decision making, which helps students transition from academia to real-world agricultural settings.

Active exchange of ideas within small groups not only increases interest among participants but also promotes critical thinking (Gokhale, 1995). Johnson and Johnson (1986) determined cooperative learning teams achieved at higher levels of thought and retained information longer than students who worked individually. Collaboration provides students with the opportunity to engage in discussion, take responsibility for their own learning and thus become critical thinkers (Totten et al., 1991). Freeman (2012) determined that a student-centered approach to learning, known as team-based learning, produced student scores that were almost always higher than those of individuals. Barron (2000) reported students earned higher scores when working on solving problems in teams versus working independently. Furthermore, student collaboration has been shown to improve students' satisfaction in the learning environment (Strong et al., 2012).

Student collaboration is important in the learning environment. In higher education, instructors can learn from students and students can learn from and with each other (Weimer, 2012). Although student collaboration has played important roles in multiple educational settings (Barron, 2000), there have been very few studies conducted on the process of student collaboration. Determining the effectiveness of student collaboration is a worthwhile endeavor for several reasons. In the absence of such information, teachers may not be able to identify which teaching strategies are effective to improve student collaboration within a given course. Decision making in a real-world environment (e.g., an operational farm) hinges upon effective student collaboration.

Social Network Analysis and Terminologies

Social network analysis (SNA) is a unique methodology that provides insights into the relationships between individuals, groups, teams, cliques, agencies and organizations (Kapucu et al., 2010). SNA provides complementary visual and statistical components that enable researchers to analyze relationships within a social network (Scott and Carrington, 2011). Although SNA has been established for several years, it is still a relatively new method for agricultural education researchers.

A social network includes a number of actors (nodes) connected by relationships (ties). Actors (nodes) can be individuals, groups, or organizations; relationships (ties) can be of any kind (e.g., formal, informal, financial, personal, professional relationship, etc.) (Davies, 2009). In a directed network, relationships (ties) have two primary directions: in and out. When a tie is sent from an actor and received by another actor, the first actor forms a tie with an out-direction, while the second actor has a tie with an in-direction (Kadushin, 2012). The directions of ties present affects the strength of a network.

Nodes and ties can be graphically reflected in a network map. Nodes can represent different attributes of participants, such as gender, course section and organizations. Those attributes can be represented by different layouts, colors, or patterns of nodes. Further, each node can be sized by different measure indices.

Measure indices provide two perspectives of analyzing networks: top down and bottom up. Top down indices evaluate how well a network works as a whole, including size, density, distance, cutpoints and blocks.

The size of a network indicates capacities of limited resources within a network (Hanneman and Riddle, 2011a). Size is indexed by counting the number of nodes where there exists a unique, ordered pair of actors; k represents the number of actors (k * k-1).

Density reflects the proportion of all possible ties present. Further, density measurers the speed at which information diffuses among the nodes (Hanneman and Riddle, 2011a).

Distance measures the efficiency of information diffusion in a network. Geodesic distance is the most commonly used concept in SNA; this shows the distance between two actors and is measured by the number of relationships in the shortest possible pathway from one actor to another (Hanneman and Riddle, 2011b).

Assuming a network is composed of several large or small cliques, a critical question worth considering is if the cliques will disconnect in the absence of certain actors. Bi-component analysis is an especially useful way to identify weak spots (cutpoints) in a network (Hanneman and Riddle, 2011b). If a node were removed, causing the structure to become divided into unconnected parts, this node is considered a cutpoint (Hanneman and Riddle, 2011b). The parts divided by cutpoints are called blocks (Hanneman and Riddle, 2011b). Therefore, cutpoints and blocks have the potential to threaten the stability of a network.

The bottom up SNA perspective focuses on each individual actor or each subgroup in the network. The most widely used approach to understand an individual actor's advantages and disadvantages is centrality (Hanneman and Riddle, 2011b). Actors who are more central to social structures are more likely to be influential or powerful (Hanneman and Riddle, 2011b). Degree is one of the typical measures showing centrality. Degree refers to the number of ties to and from a node. Since ties have directions (in and out) in a directed network, degree also has two types: in-degree and out-degree. A node's in-degree is the number of ties this node has received and out-degree is the number of ties this node has sent.

An actor with a large in-degree is a person with whom many other actors seek direct ties, indicating high prestige in a network; while actors who display a higher out-degree often have more influence within the group (Hanneman and Riddle, 2011b). In addition, N-cliques identify insights about substructures of a network (Carolan, 2013). A clique is the largest possible collection of nodes (more than two) in which all actors are directly connected to all others. N-clique is a subgroup formed by n actors. The number and magnitude of an N-clique reflects the inclusiveness of a network.

Conventional educational research has typically focused on the conceptualized behavior of individuals or groups but overlooked the relational information between or among individuals or groups (Carolan, 2013). SNA, with its corresponding computer software, has allowed researchers to determine more relational information and contribute deeper insights to observe, explain and predicate subjects' behaviors or thoughts within social networks. Researchers have used SNA to determine social interactions, diffusion of innovations, social influence, belief systems, efficacy of interventions, small-group dynamics and small-world and scale-free networks (Carolan, 2013, Roberts et al., 2010). Using SNA methodologies, Hoppe and Reinelt (2010) evaluated a leadership network, Kapucu et al. (2010) determined the change of students' friendship networks in a collaborative learning class, Prell et al. (2009) assessed stakeholders' connections with natural resources conservation initiatives; and Bartholomay et al. (2011) examined the University of Minnesota Extension's outreach to other external organizations. The literature has clearly laid out the functionality of SNA and provided guidance for the present study.

Purpose of Study and Research Objectives

The purpose of this study was to use SNA to evaluate and visualize the student collaboration network in the AGEDS 450 capstone course. Five research questions guided the study:

- Did student collaboration improve as the course progressed?
- Did each student develop more influence on decision making as the course progressed?
- Did student collaboration become more efficient?
- Did the collaboration network become more inclusive?
- Was the collapse risk of the collaboration network reduced?

Methods

Through careful review of the literature (Springer and de Steiguer, 2011; Kapucu et al., 2010; Scott and Carrington, 2011), we identified three steps necessary to answer the research questions: identifying the network, collecting social interaction data and data analysis.

Step 1: Identifying the Network

We selected a position-based approach (Laumann et al., 1983) to define the boundary of the network. In this study, the network's actors (nodes) were the 52 students enrolled in AGEDS 450 during the spring 2014 semester. Since the focus of this study was on student collaboration, the network relations (ties) were defined as relationships between students if they collaborated with each other in the course setting. The ties were either one- or two-directional and were indicated with arrows between nodes on a network map.

Step 2: Collecting Social Interaction Data

We chose the one-mode whole-network method to develop the survey instrument for data collection because this study focused on collaborative relationships linking participants (Marsden, 2011). To collect the whole-network data, participants completed a sociometric survey. The survey instrument contained a class roster and each student circled the names of other students with whom they had collaboratively worked to make decisions in the AGEDS 450 capstone course. We also used the survey to collect selected demographic information (i.e., age, major, committee assignment and year in school).

To compare the change in student collaboration over the course of the semester, we used the survey

Figure 1. Social Network Matrix Example

Participants	A01	A02	A03	A04	A05	A06	A07	...
A01		0	1	1	0	0	0	
A02	0		0	1	0	0	1	
A03	1	1		0	0	0	0	
A04	0	1	1		1	0	0	
A05	0	0	0	0		0	1	
A06	0	1	0	0	0		0	
A07	0	1	0	1	1	0		
...								

instrument at the midpoint of the semester and again at the end of the course. Fifty of 52 students completed the surveys, resulting in a 96.1% response rate. For confidentiality, each student was assigned an alphanumeric code after completing the instrument. Responses were coded into dichotomized data (1 and 0). For purposes of analysis, the code 1 meant the respondent had collaborated with a particular student; the code 0 meant the respondent had not collaborated with this student. We developed social network matrices with the dichotomized data. Figure 1 shows an example of a social network matrix. A01, A02 and A03… represent the student identification codes; 0 and 1 represent the collaboration relationship between students. In this study, two sets of social network matrices were developed: one for the survey at the midpoint of the semester and the other for the survey at the end of semester. SNA software packages use the network matrices as input to run further graphic and statistical analysis (Springer and de Steiguer, 2011).

Step 3: Data Analysis

We used UCINET, an SNA statistic and graphic software package, to analyze the matrices data. The outputs of UCINET are network maps and measures (Springer and de Steiguer, 2011). In this SNA study, the graphical analysis resulted in two sets of network maps. Measure indices included statistical analysis outcomes including size, density, distance, cliques, degree centrality (degree) and cutpoints. These outcomes provided the information necessary to answer the research questions.

Results and Discussion

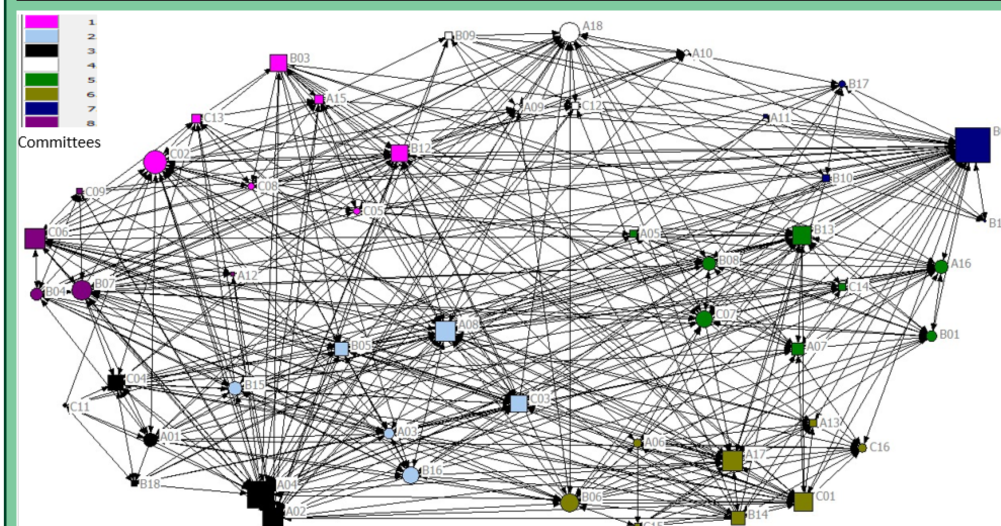
Research Question 1: Did Student Collaboration Improve as the Course Progressed?

Network maps provided a direct visualization of the structure of student collaboration in the AGEDS 450 course. Figures 2 and 3 show student collaboration network maps from the midpoint and end of the semester, respectively. Nodes on each map represent individual students and the ties (lines) represent their collaboration. There are 50 nodes on the both maps, representing the 50 students who participated in this study. In other words, the size of this network is 50 (Table 1).

Table 1. Network Size and Density

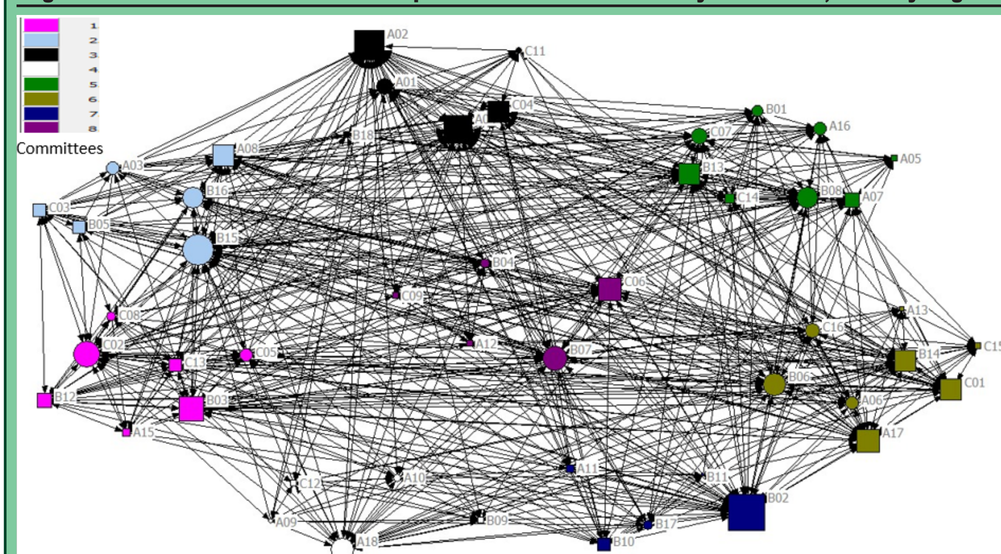
Measures	Midpoint of semester	End of semester	Rate of change (%)
Size	50	50	-
Density	0.25	0.35	+40.0

Figure 2. Midpoint-semester network map of student collaboration by committee, sized by degree.



Note. Committees: 1 = marketing, 2 = custom operation, 3 = machinery, 4 = finance, 5 = buildings and grounds, 6 = crops, 7 = public relations, and 8 = swine.

Figure 3. End-of-semester network map of student collaboration by committee, sized by degree.



Note. Committees: 1 = marketing, 2 = custom operation, 3 = machinery, 4 = finance, 5 = buildings and grounds, 6 = crops, 7 = public relations, and 8 = swine. Sections: 1 = section 1, 2 = section 2.

There are more ties on the end-of-semester map than on the mid-semester map. This reflects a change of collaboration density in the network over the course of the semester. At the midpoint of the semester, the density was 0.25; at the end of the semester, the density increased 40.0% to 0.35 (Table 1). Based on the measure of density, collaborative efforts increased as the semester progressed.

Research Question 2: Did Each Student Develop More Influence on Decision Making as the Course Progressed?

Nodes on the network maps (Figures 2 and 3) are sized by degree centrality, which is a measure that indicates power of influence in the network (Hanneman and Riddle, 2011b). On average, nodes on Figure 3 are observably larger than nodes on Figure 2. At the midpoint of the semester, the average in-degree/out-degree was 12.3 and it increased 40.0% to 17.2 at the end of the semester (Table 2). This finding indicates that on average, each student increased the number of collaborative relationships by nearly five (4.9). Each student earned higher prestige and built more influence with other students in the network over the duration of the AGEDS 450 course.

Research Question 3: Did Student Collaboration Become More Efficient?

Geodesic distance is a common measure index to show the efficiency of information diffusion in a network. The average geodesic distance between nodes was 1.88 at the midpoint of the semester and it decreased to 1.66 at the end of the semester (Table 3). In other words, if we arbitrarily select two students from the course, it took 1.88 pathways to get the students connected at the midpoint of the semester. A pathway is a direct connection (tie) between two students. At the end of the semester, 1.66 pathways were needed to connect any two students, which resulted in an 11.7% decrease in the average geodesic distance. This finding indicates that collaboration between students became closer as the semester progressed, indicating more efficiency in collaboration.

Research Question 4: Did the Collaboration Network Become More Inclusive?

At the midpoint of the semester, there were 74 cliques (Table 4). The majority (77%) of the cliques were small (3- or 4- person cliques); 18.9% of the cliques were midsize (5- person cliques); and 4.1% of the cliques were large (6- or 7- person cliques). At end of the semester, 72 more cliques were formed (Table 4). The proportion of small cliques decreased to 41.1%, midsize cliques increased to 34.9% and large cliques grew to 23.9%. The small cliques at the midpoint evolved into larger cliques by the end of semester. The network as a whole became more complex and involved more subgroups as the course progressed. This finding reflects that a more inclusive collaboration environment was formed by end of the semester.

Table 2. Average Degree of the Network

Measures	Midpoint of semester	End of semester	Rate of change (%)
Avg. in-degree	12.3	17.2	+40.0
Avg. out-degree	12.3	17.2	+40.0

Table 3. Average Distance of the Network

Measures	Midpoint of semester	End of semester	Rate of change (%)
Avg. geodesic distance	1.88	1.66	-11.7

Research Question 5: Was the Collapse Risk of the Collaboration Network Reduced?

At the midpoint of the semester, no cutpoint was found and only one block existed within the entire network (Table 5). At the end of the course, the lack of a cutpoint and total number of blocks remained the same (Table 5). This finding indicates that in the absence of any individual student, the student collaboration network had no risk of collapse either at the midpoint or end of the semester. The student collaboration network remained stable throughout the course.

Summary and Recommendations

Student collaboration in AGEDS 450 significantly improved from the midpoint to the end of the semester, after implementation of a series of collaboration-oriented course activities and assignments. Collaboration across the whole class increased, individual student influence on decision making grew, students collaborated together more immediately with higher efficiency, an inclusive collaborative environment was formed and the risk of collapse remained low. Thus, we conclude that the course design and teaching strategies used in AGEDS 450 facilitated collaborative relationships between and among students. Such relationships and the learning environment, benefit students by articulating knowledge, understanding, promoting higher order thinking and increasing group decision making (Gokhale, 1995; Lazonder, 2005). The AGEDS 450 course uses capstone course components outlined by Crunkilton et al. (1997) and student collaboration is an intentional course outcome. Specific activities derived from the capstone course components that may have led to the increase in student collaboration included group projects (e.g.,

Table 4. Numbers of N-cliques at the Midpoint and End of Semester

N-cliques	Midpoint		End	
	Number	Percent	Number	Percent
3-cliques	23	31.1%	11	7.5%
4-cliques	34	45.9%	49	33.6%
5-cliques	14	18.9%	51	34.9%
6-cliques	3	4.1%	25	17.1%
7-cliques	0	0%	10	6.8%
Total cliques	74	100%	146	100%

Table 5. Blocks and Cutpoints of the Network

Measures	Midpoint	End
Blocks	1	1
Cutpoints	0	0

State of the Farm and Strategic Issue presentations), business meetings and specific tasks (e.g., selecting seed, marketing grain, repairing buildings).

This study demonstrates a feasible and effective method to evaluate student collaboration. We encourage researchers and educators to conduct similar studies in courses that implement student-centered or team-based learning approaches, particularly capstone agriculture courses. In addition, because this study focused on one course within one semester without a control group for a true experimental comparison, the conclusion is threatened by a possibility of spontaneous growth of collaboration without any intervention. However, the interventions in this study were the course activities and assignments and it was not feasible to remove those course components.

Overall, SNA studies can help researchers and educators identify optimized teaching strategies and activities for fostering student collaboration. We recommend that additional studies expand to compare two cohorts of classes with different teaching strategies and use random grouping techniques to exclude extraneous variability, such as the natural growth of collaboration (Dinov, 2007). We also recommend increasing the frequency of network assessment (i.e., administering the SNA instrument) to more closely track the development of collaboration. Future studies should aggregate each committee into a single actor (node) to examine the multilevel networks developed within the course. This will allow for analysis of collaboration across committees, within committees and interpersonally.

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