Journal of Agricultural Education, 61(3), 38-59
https://doi.org/10.5032/jae.2020.03038

An Exploration of Student Collaboration Networks in a Team-Based Capstone Course

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Abstract

Learning is inherently a social act occurring through individualized interpretation and negotiations with diverse others. The ability to work with others within the learning environment and beyond is an essential skill. Student-centered teaching methods that emphasize active learning in a team setting have garnered much support across higher education. Recently, AGEDS 450 at Iowa State University was redesigned to further emphasize teamwork. Team-Based Learning (TBL) was incorporated within the capstone framework to promote higher levels of student collaboration, particularly for farm management decisions. TBL promotes higher order thinking and the application of course content in a real-world situation. For AGEDS 450, an actual farm serves as the applied learning laboratory where students make all decisions concerning its management and operation. This descriptive study sought to explore the collaboration networks of students enrolled in the fall 2015 (n = 61) and spring 2016 (n = 60) AGEDS 450. Social network analysis was utilized to construct and analyze student collaboration networks. Data were collected at the beginning and end of a 16-week semester in order to track development and/or growth of the collaboration network. The collaboration networks developed into cohesive structures encompassing all students within the course. With the increased interest in fostering teamwork in preparing students for careers, these results provide justification for the continued utilization of TBL. Further analysis of the TBL method is warranted with particular attention to long-term outcomes and skill attainment. It is recommended that TBL be implemented in other courses within colleges of agriculture to further examine its utility.

Keywords: collaboration; social network analysis; team-based learning; capstone course

Author Note: This research was conducted as part of a larger study. This paper is a product of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. IOWO3813 and sponsored by Hatch Act and State of Iowa funds.
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Introduction and Literature Review

The educational landscape is rapidly changing with more emphasis being placed upon learning instead of teaching (Neo & Neo, 2009). This shift to a focus on the learning process subsequently requires more collaboration among students to solve complex problems (Hoppe & Reinelt, 2010). As higher education prepares students for the workplace, teamwork, touted as an essential trait for graduates entering the workforce (Espey, 2010; Lamm, Carter, & Melendez, 2014; Lamm, Carter, Stedman, & Lamm, 2014), has been granted special consideration in course design (Han et al., 2016; Mars, 2015). Teamwork/collaboration, effective communication skills, critical thinking abilities, and

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problem-solving skills have been identified by employers as skills most desired of a four-year educational program graduate (Casner-Lotto & Barrington, 2006; Rateau et al., 2015).

Several of the aforementioned employability skills can enhance or reinforce other skills. For example, critical thinking abilities can be strengthened through communication and collaboration within the learning environment. Smith (1977) found that student–student interaction led to positive and consistent gains in students' critical thinking; a desired outcome emphasized in higher education (Rhodes et al., 2012). Totten et al. (1991) suggested that collaboration allows students to become critical thinkers by engaging in discussion and taking responsibility for their own learning. With the recent interest concerning students' critical thinking abilities within the agricultural education literature (Davis & Jayaratne, 2015; Perry et al., 2015; Perry et al., 2014; Ricketts & Rudd, 2005; Velez et al., 2015), effective communication and collaboration in the learning environment is paramount for student success (Wagner, 2008).

Through examination of the in-service training needs of secondary teachers of agriculture, Davis and Jayaratne (2015) found that teachers perceived instruction grounded in real-world scenarios, working with others, and emphasizing higher order thinking skills (e.g., critical thinking) as important for effective teaching in the 21st century. The importance of critical thinking as well as other 21st century skills within agricultural education has also been found throughout the literature with a post-secondary focus (Burbach et al., 2012; Lamm, Carter, Stedman, & Lamm, 2014; Perry et al., 2015; Perry et al., 2014; Rhodes et al., 2012, Wells et al., 2015).

Focusing specifically on critical thinking, Perry et al. (2015) concluded that enrollment in an experiential-based capstone farm management course reinforced specific critical thinking abilities. Specifically, the capstone course in his study employed discussion, written and oral communications, and issue analyses in developing critical thinking skills. The emphasis of these employability skills in higher education curriculum is needed, particularly if students are to be prepared for an evolving workforce (Rateau et al., 2015).

The ability to contribute effectively to a team can be cultivated by instructors through the emphasis of team-based or collaborative activities (Espey, 2010). In an effort to promote collaboration between agricultural science teachers and extension educators, Murphrey et al. (2011) noted the importance that should be placed on examining the organization's role in facilitating or hindering collaboration between individuals. Murphrey et al. (2011) stated "successful collaboration ultimately rests upon the commitment of individuals and the willingness for these individuals to work together and *collaborate* [emphasis in the original] with one another" (p. 38).

Social Network Analysis

While the previously mentioned research contributes to the knowledge base of agricultural education, it also illuminates the continued neglect of relational information in favor of examining strictly conceptualized behavior (Carolan, 2013). This issue is surmounted through the use and application of Social Network Analysis (SNA). "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" (Han et al., 2016, p. 178). SNA allows for relational information (e.g., collaboration) to be measured and visualized; a useful mechanism for determining student–student interaction. Adopting SNA provides a manner in which the exchange of resources among actors (i.e., individuals, groups, or organizations) in a set boundary can be examined (Haythornhwaite, 1996). Indeed, SNA is not merely a set of research methods. SNA, through a set of theories, tools, and mathematical algorithms, allows researchers to examine relationships and structures embedded within a network (Hoppe & Reinelt, 2010), specifically allowing for visualization on a graph. "Seeing the network can provide a qualitative understanding that is hard to obtain quantitatively" (Borgatti et al., 2013, p. 100).

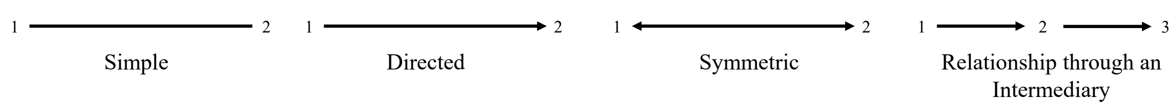
Limited literature exists concerning SNA within agricultural education settings. Roberts et al. (2010) explored interactions among student teachers during their student teaching experience. Roberts et al. noted the importance of social interaction for learning, especially during a student teaching experience. However, the study only examined the network at the end of an experience, which didn't allow for exploring the growth of the network over time. This was realized and an analysis of the formation, growth/change, and possible interventions to strengthen the overall network were recommended as areas for future inquiry.

Han et al. (2016), explored the change in the collaboration network in an undergraduate capstone course when measured at the midpoint and end of a semester. As the semester progressed, inclusivity increased. That is, students collaborated more with one another (student–student interaction). Further, Han et al. postulated that the capstone course design and the learning activities implemented facilitated collaboration among the students.

While SNA has been utilized for many years, it is still a novel method for researchers in agricultural education (Han et al., 2016). Thusly, SNA appears to be an innovative approach for measuring teamwork/collaboration within a course that encourages and emphasizes student–student interaction. With SNA's novelty within agricultural education in mind, it is appropriate to discuss some concepts, definitions, and explanations offered by this approach.

The simplest network contains two actors, and a relationship that links them (Kadushin, 2012). Relational data is derived from contacts or connections between interacting actors (Scott, 2013). Relationships in networks can be classified as simple, directed, symmetric, and relationship through intermediary (Kadushin, 2012). Two actors in one location could define a simple relationship, where the relationship is not directed in any way. In a directed relationship, actor one *likes* actor two, however the feeling is not returned. A symmetric relationship occurs when actor one *likes* actor two and vice versa. Relationships through an intermediary occur when information flows from one actor to another, and eventually is passed on to an additional actor. The relationship is directional but is not reciprocal (Kadushin, 2012). Figure 1 displays the various types of relationships in SNA.

Figure 1
Types of Relationships in SNA



Note. Adapted from "Understanding Social Networks," by C. Kadushin, 2012.

Actors, or nodes, can be individuals, groups, or entire organizations, and are characterized by attributes (Borgatti et al., 2013). Attributes distinguish actors from one another, generally in a categorical way (e.g., gender, age, college major, or enrollment in a specific section of a course). Relational data is of particular importance to social network studies; advice giving, communication, and friendship ties being some of the most commonly studied relations within networks (Borgatti et al., 2013). Basic or applied network analyses are the two main approaches; where applied "…mean[s] that the study consists of calculating a number of metrics to describe the structure of the network or capture aspects of individuals' positions in the network" (Borgatti et al., 2013, p. 6), whereas basic network analyses "…try to describe the variance in certain variables as a function of others" (Borgatti et al., 2013, p. 6).

The metrics utilized to describe the structural characteristics of networks are plentiful. Hanneman and Riddle (2011) noted that measures are grounded with theoretical logic and empirical confirmation and they contribute significantly to the understanding of local and global networks. Common concepts and measures for describing networks are included in Table 1.

Table 1

Definitions of Social Network Analysis Concepts and Measures

Concepts and Measures	Definition
Dyad	Two objects connected by some sort of relationship[a]
Triad	Network of three objects connected by relationships[a]
Size	The number of actors/nodes in a network[b]
Density	The proportion of all possible ties actually present in a network[b]
Reachability	Existence of a set of connections where every actor is connected to another, regardless of path length[b]
Connectedness	The proportion of pairs of nodes that can reach one another by a pathway of any length[c]
Geodesic Distance	Number of relations in the shortest pathway that connects two actors[b]
Eccentricity	An actor's largest geodesic distance[b]
Diameter	Largest eccentricity present in a network[b]
Compactness	A measure that weighs paths connecting nodes inversely by their length[c]
Reciprocity	Proportion of reciprocated ties to total number of ties[c]
Transitivity	Measure of the occurrence of transitive or intransitive triads[c]
Clustering	A set of actors judged to be similar on the basis of relational data[b]
Robustness	A measure of how many nodes need to be removed in order to disconnect the network[c]
Degree	Number of connections[c]
Indegree	Measure of ties sent from other actors to a target actor in directed networks[c]
Outdegree	Number of ties sent from target actors to other actors in directed networks[c]
Cohesion	The extent that actors within a network are connected[b]

Note. Common terms utilized in analyzing social networks. [a]Kadushin (2012); [b]Hanneman and Riddle (2011); [c]Borgatti et al. (2013).

Theoretical/Conceptual Framework

Bandura's (1977) Social Learning Theory (SLT) and Vygotsky's (1978) social constructivism served as the theoretical underpinnings of this study. Initial focus within the SLT framework focused on behaviors of the individuals, while social constructivism focused mainly on cognition. Both theorists discuss the importance of interaction with others for individual development.

The coalescence of "…speech and practical activity, two previously completely independent lines of development…" (Vygotsky, 1978, p. 24) is the most significant moment in intellectual development. Doolittle and Camp (1999) identified social constructivism as a continuum. Learners construct meaning from their experiences and constructivism acknowledges the active role students (individually and socially) take in the creation of knowledge (Doolittle & Camp, 1997; Fosnot, 2005). Prawat and Flodden (1994) noted that "…knowledge evolves through a process of negotiation within discourse-communities and that the products of this activity… are influenced by cultural and historical factors" (p. 37). The influence of cultural and historical factors in knowledge creation highlight the interplay of the individuals' contribution to the social aspect of creating knowledge.

Roberts et al. (2010) described the social nature of learning by stating, "The dynamic process of knowledge acquisition relies on social interactions to clarify knowledge and process experiences" (p. 113-114). Knowledge is a social product that is created and shared within communities (Mercer & Howe, 2012). Supportive of Social Learning Theory (Bandura, 1977), the interaction within the learning environment is viewed as the interplay of behavior, personal factors, and environmental factors, further explained as "…interlocking determinants of each other" (p. 10). Bandura (1977) further noted the varying degrees of influence these factors have in different situations. In one situation, personal factors may exert more influence over the environmental or behavior factor, while other situations may lead to the environment exerting more influence, and so on. The effects of social interaction may have lasting impacts on long term outcomes and student success. An important aspect of SLT (Bandura, 1977) is the emphasis of self-regulation, explained "by arranging environmental inducements, generating cognitive supports, and producing consequences for their own actions, people are able to exercise some measure of control over their own behavior" (Bandura, 1977, p. 13). The environmental inducement in the present study is the structure of AGEDS 450 in TBL format.

AGEDS 450 and Team-Based Learning

AGEDS 450, a capstone farm management course, is by nature, social. The course has been designed to foster teamwork and collaboration in several ways. The instructional approach itself, as well as the specific course assignments, were designed to allow students to work together to solve problems (Andreasen & Trede, 2000; Paulsen, 2010). A brief history of the course, supported by existing literature on the actual course, and the current layout, as described by the researchers' experience in the course redesign is appropriate. The course, beginning in 1943, was developed in order to provide students with practical experience in making farm management decisions (Murray, 1945). The students were tasked with making all decisions as it related to an actual farm, and did so through the analysis of available data and official business meetings (Murray, 1945).

Wallace (1963) noted the power of peer influence within the course and that each decision was subjected to sound justification and presentation of the reasoning and supporting evidence to other class members. Learning to deal with consequences of decisions enhanced the educative power of the course; students had to deal with decisions that had negative consequences such as the installation of a lane fence in a hay field that had to be removed in order for the hay wagon to make a turn. While the fence was approved by a majority vote after presentation of the plan and justification for its installation, it ended up being a poor decision but a powerful lesson (Murray, 1945). Students were required to synthesize decisions from each year and present to course alumni in an effort to keep them up-to-date on the progress of the farm. This synthesis was also paired with a farm field day where all course alumni were invited to visit the farm and see how the previous decisions impacted the farm (Wallace, 1963). Students in the AGEDS 450 have been tasked with working together to make sound management decisions, as the farm was expected to be a self-sustaining entity (Murray, 1945; Wallace, 1963).

Teamwork/collaboration has long been a staple of the course design. With the emphasis on teamwork/collaboration to manage a real farm, Honeyman (1985) stated:

> During the discussions, students often learned from each other. New ideas and original approaches were gained through interaction with those of differing backgrounds or experiences. Frequently students often came to know their AGEDS 450 classmates better than those in any other college course (p. 56).

Echoing an assertion from Honeyman (1985), Trede et al. (1992) concluded the use of a farm laboratory contributed most to the effective teaching of the course, and that students developed deep interpersonal relationships. In a follow-up study of course alumni, Andreasen and Trede (2000) found that student-student interaction in the AGEDS 450 far exceeded the student-student interaction in similar capstone courses. From inception to present, the social aspect of learning has seemingly contributed to the delivery employed.

Specific course design or teaching methodologies may prove to be an effective way to increase collaboration among students, as embedding employability skills can be done without compromising content (Knight & Yorke, 2002). Capstone experiences have been effective in student development of teamwork/collaboration skills (Andreasen & Trede, 2000; Crunkilton et al., 1997; Han et al., 2016; Honeyman, 1985; Paulsen, 2010; Perry et al., 2015; Trede & Andreasen, 2000; Trede et al., 1992); thusly, they are classified as a high-impact educational practice (Kuh, 2009). In an effort to further emphasize teamwork and collaboration, the AGEDS 450 course was recently restructured to a Team-Based Learning (TBL) format (McCubbins et al., 2018).

TBL was developed in the late 1970s in an effort to ameliorate the effects of substantial growth in course enrollment (Michaelsen et al., 2004; Michaelsen et al., 2008; Michaelsen et al., 2011; Sibley & Ostafichuk, 2014). Michaelsen et al. (2004) explained TBL as a teaching method which emphasizes team problem solving and decision making through the application of course content. In this method, the time normally devoted to passive transmission of content is transformed into an active learning environment that provides ample opportunities for students to apply content to real world scenarios (Michaelsen et al., 2011; Sibley & Ostafichuk, 2014).

In TBL structured courses, students are responsible for engaging in introductory content before attending a class session, and further held accountable for their engagement with the content via an individual readiness assurance test (IRAT) (Michaelsen et al., 2008). An additional layer of accountability is introduced through the team readiness assurance test (TRAT), which allows students to collaborate and negotiate each question on the IRAT (Sibley & Ostafichuk, 2014). The TRAT is completed on an Immediate Feedback Assessment Technique form that provides immediate feedback to the team. Teams, if they collectively agree, are able to appeal questions on the TRAT based on ambiguity in the question or other glaring errors within the assessment; however, the appeal must be based on written scholarly prose, and is not an opportunity to 'dig' for points (Michaelsen et al., 2004; Michaelsen et al., 2008; Michaelsen et al., 2011; Sibley & Ostafichuk, 2014). Any misconceptions regarding the introductory content are addressed in a short, corrective instructional session (McCubbins, 2015). After this is completed, students spend the majority of class time applying the content to solve real-world problems and make informed decisions (Michaelsen et al., 2004). Student teams are intact for the duration of the semester so that they may transform into cohesive, high performing learning teams (Michaelsen et al., 2011; Sibley & Ostafichuk, 2014). McCubbins et al. (2016) postulated that capstone courses taught in contextual setting would benefit from the adoption of a student-centered teaching method that emphasizes teamwork and collaboration.

Exploring and describing collaboration networks in an active, learner-centered classroom can provide valuable insight on how social structures form and the intensity that students engage in collaborative activities. As noted previously, teamwork/collaboration and communication are skills desired by employers; aside from the traditional behavioral conceptualizations of these skills, social network analysis, and visualizations of such concepts may provide ample evidence for adoption of a learner-centered approach within classrooms across the discipline.

Purpose and Objectives

Sociograms, developed through network analysis methods and viewed through a social constructivist lens, can provide insight on the intensity of the high-impact practice of collaboration within courses across higher education institutions. The purpose of this descriptive study was to explore the collaboration between students over the duration of a semester in a team-based learning formatted capstone course. Data collection included an initial and end-of-semester measure of reported collaboration. An apparent gap in the literature exists in terms of measuring student collaboration, especially through a multiple-measure approach. This study sought to explore the development of a collaboration network during a 16-week capstone course that emphasized teamwork and communication (Crunkilton et al., 1997). Perry et al. (2014) declared a need for instructors within higher education institutions to utilize innovative teaching methods that target specific skills that aid in the development of critical thinking abilities. The apparent gap in the literature, the declaration from Perry et al. (2014), as well as priority area four of the National Research Agenda: Meaningful, Engaged Learning in All Environments (Edgar et al., 2016) provides support for the need to investigate collaboration networks among students. The following research questions guided this study:

1. What does a collaboration network map look like in a team-based learning formatted course?
2. Does the collaboration network map change over the course of the semester?
3. Did the collaboration network become more inclusive?

Methods and Procedures

Design and Population

This study was part of a larger research study that sought to examine the effectiveness of the TBL pedagogical practice in an undergraduate capstone course from multiple perspectives. The present study sought to explore and describe the development of, and potential growth of social networks in a TBL formatted capstone course. SNA studies are often developed in three stages (Kapucu et al., 2010; Scott & Carrington, 2011; Springer & de Steiguer, 2011). This study, employing a non-experimental design, followed the aforementioned stages and included; 1) identifying the network, 2) collecting social interaction data, and 3) analyzing the resulting data. A full network, position-based approach, as outlined by Laumann et al. (1983), was utilized to define the boundary of the network. Since the target population consisted of students enrolled in the AGEDS 450 course during the fall 2015 (n = 61) and spring 2016 (n = 60) semester, a census was conducted, and served as the boundary definition of the network, for each semester. Network diagrams were created for each time point of data collection for each semester. The resulting networks were analyzed independently as the interest was focused on the growth and development of the networks within the TBL formatted course.

Instrumentation

Data were collected on a researcher-created, paper-based, sociometric questionnaire (Moreno, 1953). The survey included selected demographic data (i.e., team number, age, lab section, major, class status, and committee), a class roster, and instructions on filling out the instrument. Participants were instructed to identify only students with whom they had collaboratively worked, and to rate that level of collaboration. Previous relationships were not of interest in the current study; therefore, students were instructed to only rate the collaboration with other students during this specific course. The levels of collaboration were summarized on a five-point scale ranging from no collaboration (0) to high-level collaboration (4). In order to assess the growth and development of any resulting network, a semester-long multipoint assessment was conducted with the sociometric survey. The sociometric survey was distributed after the first week of the course and again during the last week of the 16-week semester. This was repeated for both fall 2015 and spring 2016 semesters. Response rates for the fall 2015 (n = 61) and spring 2016 semester (n = 60) were 100% (N = 121).

Figure 2 depicts the student response options for reporting collaboration with other students. *No collaboration* was defined as not seeking information or input for various assignments or projects during the course. *Low level collaboration* was described as seeking minimal information or input from others for assignments or projects while *high level collaboration* was defined by significant contributions of information or input from others for completion of assignments or projects. These definitions were reiterated at each point in the data collection process.

Figure 2
AGEDS 450 Sociometric Response Options

Student Name 1 2 3 4	Student Name (1) 2 3 4	Student Name 1 2 3 (4)
No collaboration	Low level collaboration	High level collaboration

Data Management

Before data analysis could be completed, reported data had to be coded, and input into a social network matrix. Data management included alpha-numerically coding each individual student, and creating a full matrix including all reported relational data (i.e., collaboration). The first row and column identified the node and the information within the cells indicated a relation. The relational information can be binary (i.e., 1s and 0s) or valued (i.e., 0, 1, 2…), where binary data may indicate a relation or not and valued data may indicate a level of relations. For example, binary data could indicate that node A reports node B is a *friend* and would be indicated with a 1, while valued data could be measured by how often actors interact with others or how strongly they rate their *friendship* and be indicated with a predetermined measure (e.g., 1 = acquaintances, 2 = close friends, 3 = best friends). Symmetric matrices are those where the lower left section of the matrix mirrors the top right portion ($x_{ij} = x_{ji}$), while directed ties utilize an asymmetric matrix where x_{ij} could equal x_{ji} but does not have to (Borgatti et al., 2013). Figure 3 shows an example of a non-reflexive network matrix (Borgatti et al., 2013). For this study, the data were dichotomized before analyses were conducted for interpretability purposes. Descriptive statistics for explaining networks were performed in UCINET (Borgatti et al., 2002). Specific measures calculated included; density, average degree, average geodesic distance, reciprocity, transitivity, blocks, cutpoints, diameter, and number of ties (actually present and total possible). Network visualizations were diagramed with NetDraw (Borgatti, 2002). All procedures performed contribute to explaining the networks that emerged from each time point of relational data collected. A separate matrix was created for the attribute data collected. The rows represented each actor while the columns represented specific attributes of each node. Figure 4 illustrates an attribute matrix and its components.

Figure 3
Sample Adjacency Matrix

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

Note. Adapted from "Analyzing Social Networks," by S. P. Borgatti, M. G. Everett, and J. C. Johnson, 2013.

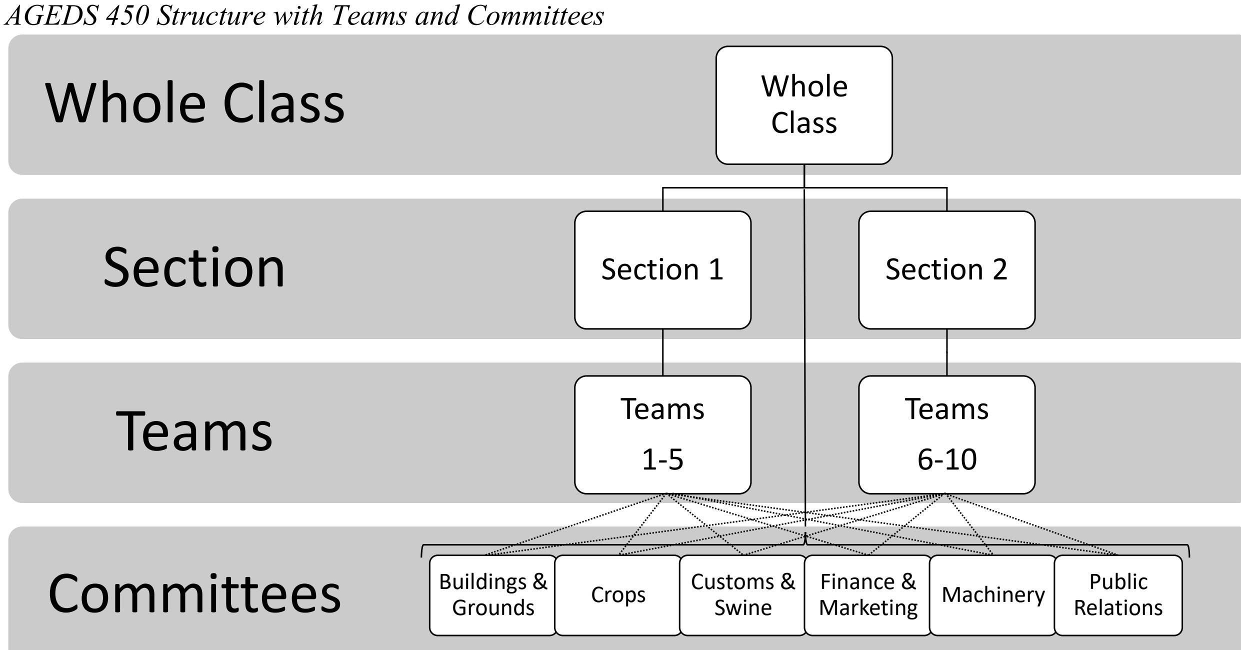
Figure 4
Sample Attribute Matrix

		Attributes						
		Team #	Age	Section	Major	Status	Committee	...
Participants	A01	1	22	1	1	3	1	
	A02	2	21	1	1	3	2	
	A03	3	25	1	1	4	1	
	A04	4	22	2	1	4	3	
	A05	5	21	2	1	3	5	
	...							

Note. Adapted from "Analyzing Social Networks," by S. P. Borgatti, M. G. Everett, and J. C. Johnson, 2013.

As noted in Perry et al. (2015), the AGEDS 450 structure is unique. Perry et al. contended that the structure offers ideal conditions for experimental research design because the course has two laboratory sections. This can be argued for small-scale research. However, the entire class met in an on-campus facility for the lecture portion of the course on Tuesdays, which would introduce a serious threat of diffusion. Laboratory sections met separately on Wednesdays and Thursdays each week and consisted of roughly half of the students in each section. In an effort to promote collaboration as well as handle increasing enrollment, TBL was couched alongside the capstone course tenets expounded by Crunkilton et al. (1997) and McCubbins et al. (2019). Figure 5 displays how the teams and committees were structured.

Figure 5
AGEDS 450 Structure with Teams and Committees



Note. Reprinted from *Student perceptions of their experience in a TBL formatted capstone course* (p.138) by OP McCubbins, T. Paulsen, R. Anderson, 2018. Reprinted with permission.

Each semester had 10 teams of five to seven students. Teams were created via criterion-based measures in order to ensure a distribution of academic resources (e.g., academic performance, work experience, major, etc.). The teams were contained within sections, meaning teams one through five were in section one and team six through ten were in section two. To encourage the formation of multiple networks and to promote exposure to several perspectives, teams determined committee representation. The committees represented the various enterprises found on the farm. Committees were distributed across sections allowing for half of each committee to be present on any given lab day. Importantly, teams made decisions regarding the management and operation of the farm while committees actually researched and carried out any decisions made. For example, if the teams decided to market grain, the finance and marketing committee would then be responsible for ensuring the execution of the contract.

Results

The findings, presented in two sections, describe the collaboration networks from fall 2015 and spring 2016 semesters. For each semester, whole network descriptions and diagrams are presented first, followed by team network descriptions and diagrams.

Fall 2015 Whole Network

Eighty percent (*n* = 49) of the students who participated in this study were male, and 20% (*n* = 12) were female. Section one of the separate labs, which housed teams one through five, contained 48% (*n* = 29) of the students while section two, which housed teams six through ten, contained 52% (*n* = 32) of the students. Agricultural studies was the academic major for 100% (*N* = 61) of the students in the population.

The first research question sought to determine the structure of a collaboration network map from the TBL formatted capstone course. Sociometric data for Round I (Figure 6) and Round II (Figure 7) are depicted in graphical form and provide a visualization of the relational structure of a collaboration network. The sociograms provide visual evidence of an increase in the number of collaborative ties between all students in the course. The sociograms reveal no isolated individuals and appear more dense from round one to round two.

Figure 6

Fall 2015 Round I Collaboration Network

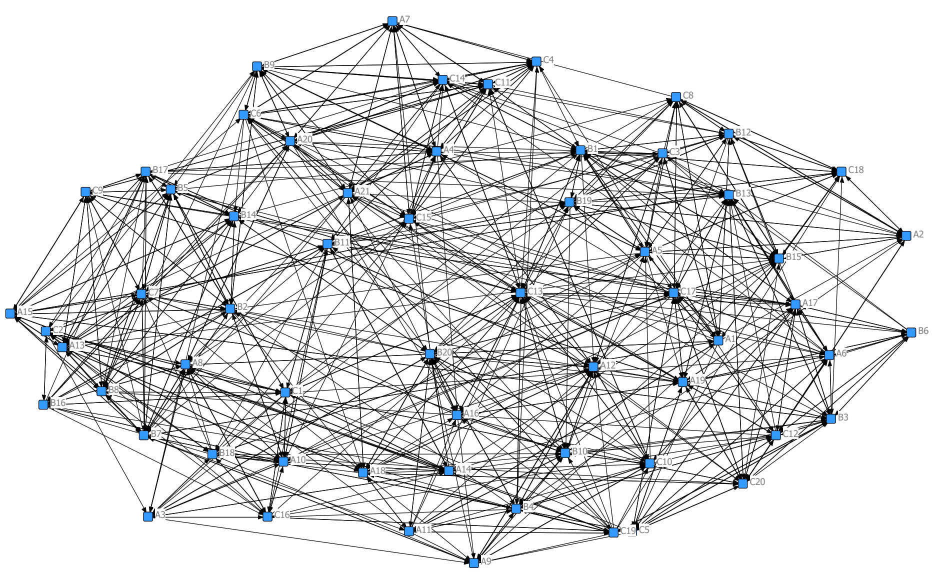
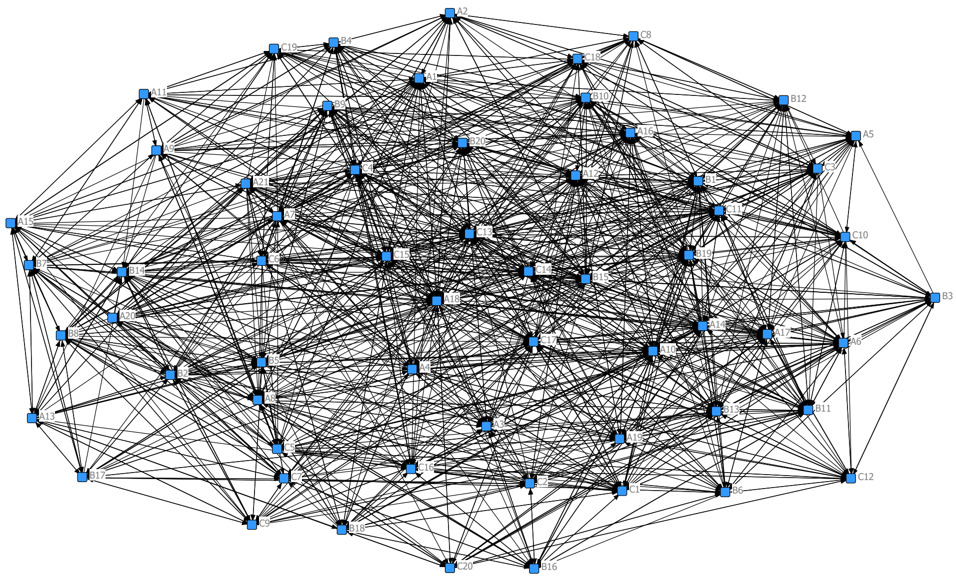


Figure 7
Fall 2015 Round II Collaboration Network



Determining change in the collaboration network was the purpose of the second research question. Whole network descriptive statistics were calculated as well as the percent change for each round of data collection. Whole network descriptive statistics are provided in Table 2 while Table 3 highlights change percentages for the density, number of ties, average degree, and the average geodesic distance between actors. Research question three was concerned whether or not the network became more inclusive. The density of the initial collaboration network was 0.21, representing 753 unique collaboration ties out of 3,660 possible ties. The density of the final collaboration network was .36, representing a 71.4% increase in the overall density of collaborative relations.

Table 2 displays the network properties for both rounds of data collection and the percent change of the primary measures of the network. The diameter, blocks, and cutpoints remained constant through each measure of collaboration at 3, 1, and 0, respectively. The density of collaboration ties for the whole network increased by over 70% while the average geodesic distance between actors experienced a continual decrease from the initial to the final measure. In other words, the average number of pathways to connect a student to any other student was lowered, indicating a more collaborative network.

Table 2
Collaboration Network Properties for Fall 2015

Measure	Round I	Round II	Percent Change
Density	0.21	0.36	71.4
Standard Deviation	0.40	0.48	-
Average Degree	12.3	21.4	73.9
Average Geodesic Distance	1.92	1.65	-14.1
Standard Deviation	0.60	0.50	-
Reciprocity	0.58	0.57	-
Transitivity	0.14	0.19	-
Blocks	1	1	-

Table 2
Collaboration Network Properties for Fall 2015 Continued…

Cutpoints	0	0	-
Diameter	3	3	-
Number of Ties (Actual)	753	1306	73.4
Number of Ties (Possible)	3660	3660	-

Fall 2015 Team Network

Table 3 displays descriptive statistics for the team network for each round of data collection as well as the percent change of the team's collaboration ties densities. Each team had a positive change in density from the beginning to end of the semester, which indicates that the teams collaborated more as the semester progressed. All ten teams ended the semester with an increase in the density of collaboration. Six of the ten teams experienced a 40% growth of within-team density of collaboration. The lowest growth in terms of percent change in density was 26.3% within team nine.

Table 3
Within-Team Collaboration Network Properties for Fall 2015

	Round I		Round II		
Team	Ties	Density	Ties	Density	Percent Change
1	12	0.40	24	0.80	50.0
2	14	0.47	27	0.90	47.8
3	21	0.70	29	0.97	27.8
4	18	0.60	26	0.87	31.0
5	16	0.53	27	0.90	41.1
6	21	0.50	37	0.88	43.2
7	12	0.40	25	0.83	51.8
8	18	0.43	32	0.76	43.4
9	14	0.70	19	0.95	26.3
10	19	0.63	27	0.90	30.0

Sociograms arranged by teams are presented for Round I (Figure 9) and Round II (Figure 10) and confirm the growth of collaboration among and between teams in AGEDS 450 throughout the semester.

Figure 9
Fall 2015 Round I Team Collaboration Network

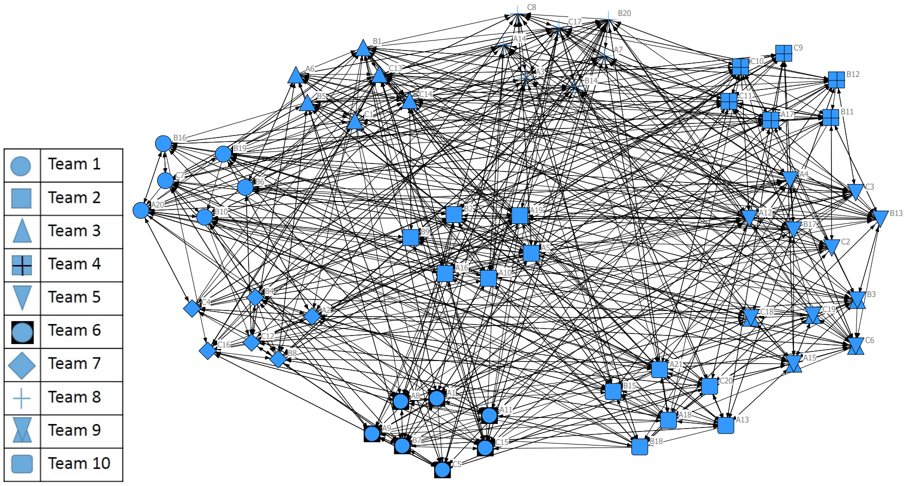
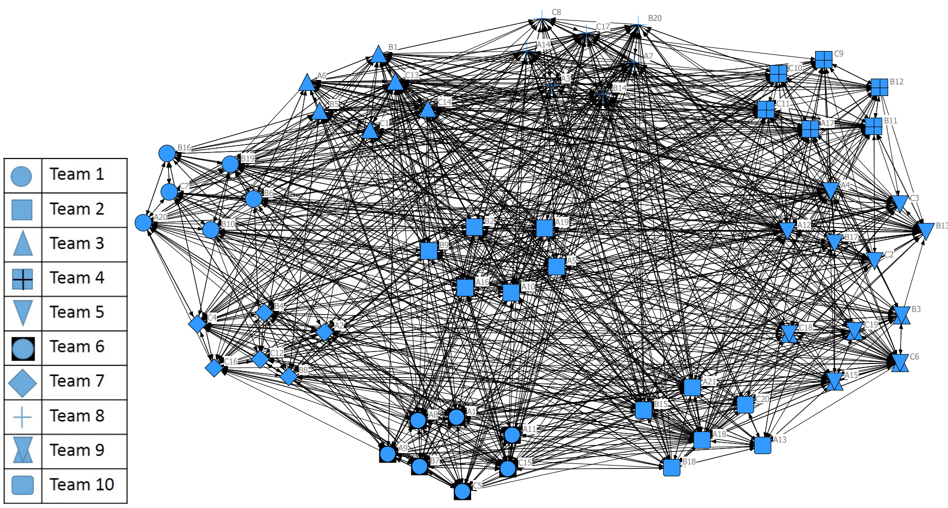


Figure 10
Fall 2015 Round II Team Collaboration Network



Spring 2016 - Whole Network

Eighty-three percent (*n* = 50) of the students were male, and 17% (*n* = 10) were female. Section one, which housed teams one through five, contained 50% (*n* = 30) of the students while section two, which housed teams six through ten, contained 50% (*n* = 30) of the students. All 60 students (100%) were pursuing a degree in Agricultural Studies with one student pursuing a double major in Agricultural Studies and Speech Communications.

The first research question sought to determine the structure of a collaboration network map from a TBL formatted capstone agriculture course. Sociometric data for Round I (Figure 11) and Round II (Figure 12) are depicted in graphical form and provide a visualization of the relational structure of a collaboration network. Examination of the sociograms reveal that node C2 (lower right) has the potential to be isolated in Round I, but is more connected to the overall network in Round II.

Figure 11
Spring 2016 Round I Collaboration Network

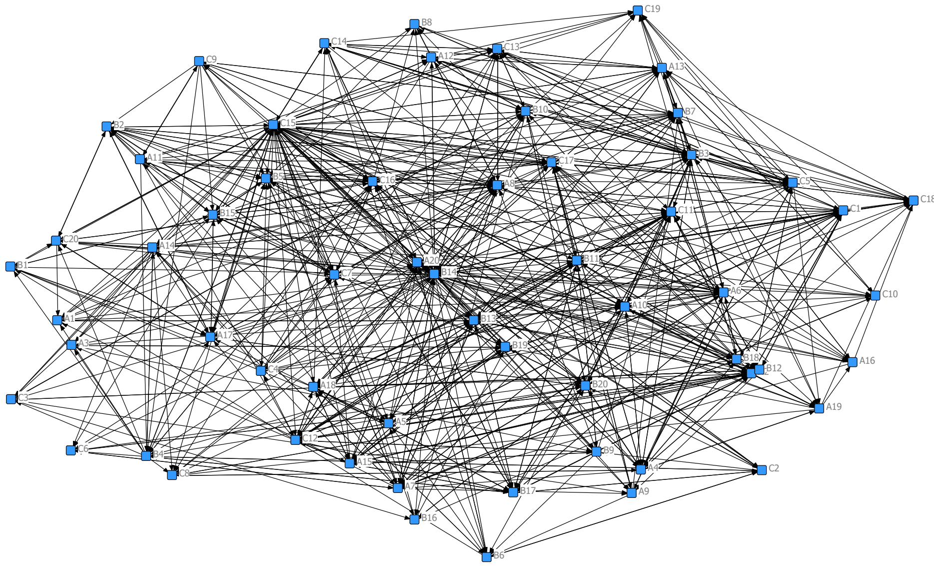
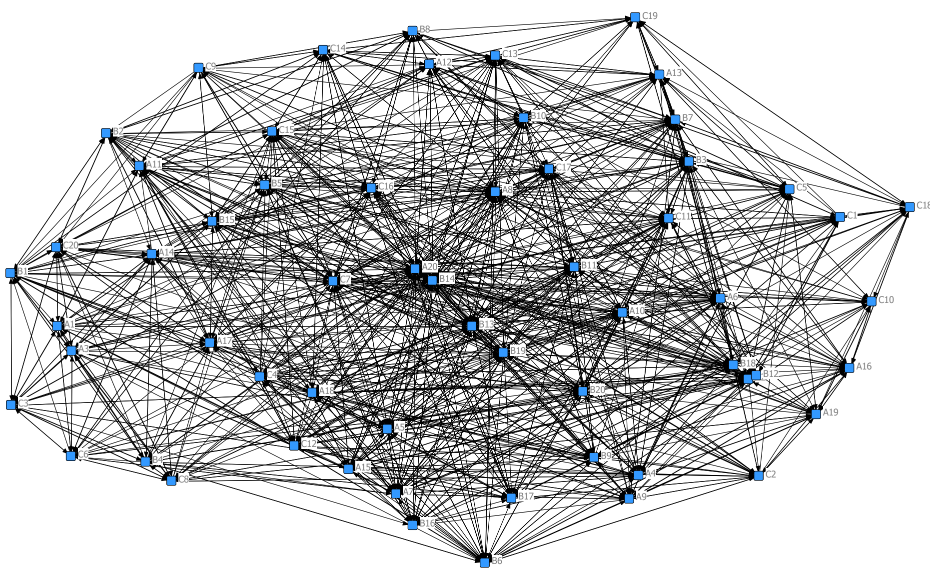


Figure 12
Spring 2016 Round II Collaboration Network



The second research question was addressed by calculating descriptive statistics for the whole network and then calculating the percent change for specific network characteristics. Table 7 provides descriptive statistics for the whole network for both rounds of data collection and the percent change for the main network measures. Determining the density of collaboration within the AGEDS 450 course addresses research question three. The network density increased from 0.19 from the initial measure to 0.35 at the end of the semester, an 84.2% increase. Actual ties within the network increased 78.5% from Round I to Round II, meaning more students engaged in collaborative relations with other students.

Table 7
Collaboration Network Properties for Spring 2016

Measure	Round I	Round II	Percent Change
Density	0.19	0.35	84.2
Standard Deviation	0.39	0.48	-
Average Degree	11.6	20.7	78.4
Average Geodesic Distance	1.97	1.65	-16.2
Standard Deviation	0.61	0.48	-
Reciprocity	0.42	0.58	-
Transitivity	0.19	0.17	-
Blocks	1	1	-
Cutpoints	0	0	-
Diameter	4	3	-
Number of Ties (Actual)	697	1244	78.5
Number of Ties (Possible)	3540	3540	-

Spring 2016 Team Network

Table 8 displays descriptive statistics for the within-team density for each round of data collection. The percent change of the within-team density for each round is reported as well. Six of the ten teams had exhibited an increase in their network density from Round I to Round II. Two teams experienced a decrease in collaboration and two teams showed no change from Round I to Round II. At the conclusion of the semester all ten teams ended the semester with an increase in the density of their within-team collaboration. Visualization of the network arranged by teams is provided for Round I (Figure 13) and Round II (Figure 14).

Table 8
Within-Team Collaboration Network Properties for Spring 2016

	Round I		Round II		Percent
Team	Ties	Density	Ties	Density	Change
1	17	0.57	26	0.87	34.5
2	12	0.60	17	0.85	29.4
3	27	0.90	29	0.97	7.2
4	7	0.35	16	0.80	56.3
5	10	0.24	23	0.55	56.4
6	16	0.53	19	0.63	15.9
7	24	0.57	35	0.83	31.3
8	11	0.37	20	0.67	44.8
9	5	0.17	17	0.57	70.2
10	21	0.70	29	0.97	27.8

Figure 13
Spring 2016 Round I Team Collaboration Network

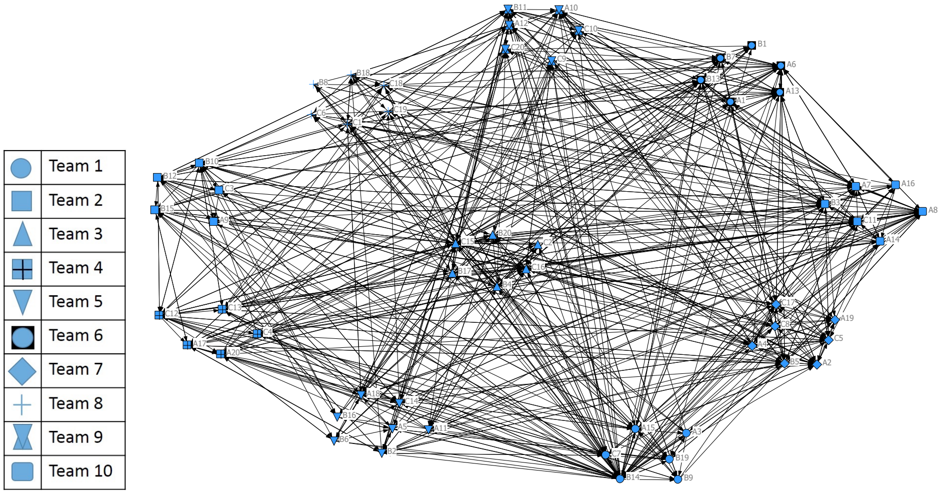
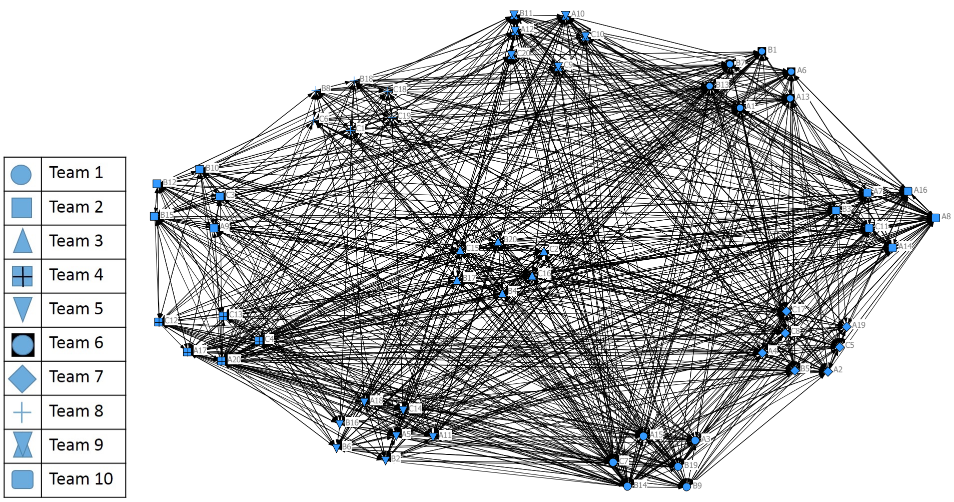


Figure 14
Spring 2016 Round II Team Collaboration Network



Conclusions and Discussion

Research question one sought to determine the structural characteristics of a collaboration network in a TBL formatted capstone course. The network characteristics for the whole network were strikingly similar across semesters. Density for the fall 2015 Round I and Round II measures were 0.21 and 0.36, respectively. Similarly, the density for Round I and II in the spring 2016 network were 0.19 and 0.35, respectively.

The second research question sought to measure the change in the collaboration networks over the semester. Both semester's networks experienced substantial growth in terms of number of collaborative relationships. Based on the findings of this study, we conclude that the TBL formatted AGEDS 450 course promoted and nurtured collaboration between students. These findings provide validation of this method as Crunkilton et al. (1997) stressed the importance of promoting small group work. TBL seemingly hampers the "hindering element" of large class sizes in a capstone course as well (Crunkilton et al., p. 9).

Research question three sought to determine if the collaboration networks became more inclusive. The global collaboration network (i.e., whole network) sociograms show dramatic increases in the density of collaboration. Density of the global collaboration network for the fall 2015 semester increased 71.4%, while the spring 2016 density increased 84.2%. The existence of only one block and no cutpoints of the global network across both semesters highlight the stability of the network and no risk of network collapse. In other words, the removal of an individual student would not significantly affect the collaboration network, a finding in congruence with Han et al., (2016).

The AGEDS 450 course is designed utilizing Crunkilton et al.'s (1997) framework for capstone courses which emphasizes teamwork, communication, decision-making, problem-solving, and critical thinking. Based on global network properties, we conclude that teamwork and communication outcomes are being adequately addressed within this specific capstone course. These findings further support the claim that learning is a social activity (Bandura, 1977; Doolittle & Camp, 1999; Roberts et al., 2010; Vygotsky, 1978).

The development of dense, cohesive collaboration networks also supports Honeyman's (1985) assertion that students learned from one another and developed friendships that will last beyond their affiliation with AGEDS 450. Although performance was not measured in the present study, the growth and development of the collaboration networks align with Bandura's (1977) explanation of environmental, personal factors, and behaviors as being bidirectional determinants of learning.

In regard to local networks (i.e., team network), it can be concluded that teams became more cohesive as the semester progressed, aligning with previous research that found permanent teams develop into cohesive units in TBL formatted courses (Michaelsen et al., 2011; Sibley & Ostafichuk, 2014). Though not specifically measured, students' valuation of teams would appear to be high, as they continued to engage in collaborative relationships with other students and did so at a higher frequency as the semester progressed. The reciprocity within the global network would suggest that students continued to engage in or seek new collaborative relations with others because they are beneficial to the learning process (Michaelsen et al., 2004; Sibley & Ostafichuk, 2014). It is further assumed that a significant amount of information was distributed throughout the collaboration networks as students made all decisions in order to manage the farm, the lab component of the course.

Overall, we conclude that the students in the TBL formatted AGEDS 450 course were willing and committed to the process of collaboration. This conclusion is evidenced by the substantial growth in collaborative relationships at the local and global levels of the network as the semester progressed.

Recommendations and Implications

The findings from this study led to the development of several recommendations for practice and for future research. The TBL-formatted AGEDS 450 course provided an environment that supported and nurtured student–student interaction, specifically collaboration. The amount of collaboration continually increased throughout the semester. Instructors who wish to foster collaboration and student self-regulation should consider the adoption of active, student-centered teaching methods that include teams. We recommend special consideration be granted in course design and course revisions in an effort to foster teamwork/collaboration, as well as other 'employability skills' (Han et al., 2016; Knight & Yorke, 2002; Mars, 2015).

Instructors of capstone courses, particularly those who follow the Crunkilton et al. (1997) framework, should participate in professional development activities that focus on the integration of employability skills (Perry et al., 2015). Particular interest should be focused on developing the ability to effectively promote student–student interaction; as this has been shown to increase critical thinking abilities, as well as problem solving and decision-making abilities of students (Davis & Jayaratne, 2015; McCubbins et al., 2016; McCubbins et al., 2018; Michaelsen et al., 2008; Sibley & Ostafichuk, 2014; Smith, 1977; Totten et al., 1991).

For researchers interested in examining the nature of social network structure in capstone agriculture courses, this study, along with Han et al., (2016), describe a feasible method to collect and analyze sociometric data. This information could be utilized to create deeper insights on specific phenomenon examined within the discipline of agricultural education.

Recommendations for future research are plentiful. First, with the assumption that learning is social in nature and that personal, behavioral, and environmental factors are reciprocal determinants of one another (Bandura, 1977), we recommend special attention be given to the environmental factor in future research regarding teaching methods. Of particular interest is in determining specific teaching methods or activities that support or hinder student–student collaboration. We recommend this study be replicated and consider additional attributes (variables). The application of SNA with performance data and/or student-perceived values of teams could offer significant insight into the social nature of learning in a multitude of environments. Additionally, pairing a qualitative component with SNA could provide extremely rich data in terms of how students make meaning and construct knowledge in social contexts. Teamwork/collaboration skills have been consistently mentioned as lacking in graduates (Casner-Lotto & Barrington, 2006; Rateau et al., 2015); perhaps the adoption of TBL, or other teaching methods that emphasize teamwork, can offer a solution to this dilemma.

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