Levels of Social Network Analysis and Small Team Problem Solving in the Classroom

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Abstract

In a collaborative learning environment, transfer of knowledge depends strongly on sociocultural factors including the interaction among the learners as well as the interactions with the instructor. An understanding of some of the factors that affect the dynamics of learners and learning can be gleaned through the use of social network analysis (SNA). 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, which may affect what and how a student learns and his/her problem solving ability.

This paper presents a study of the levels of the social network of students in an engineering project course. The analysis is done in the context of a design task given to small teams of students. The quality of the final design is evaluated using a rubric that yields a quantifiable result. We relate the team members' perceptions of their network with the problem solving ability of the team.

We found significant correlations between a team's project score and a team's balance as well as with the individual student's perception of their team balance, although the sample size was small. In this context, the balance of a team is the degree to which feelings are reciprocated, as discussed in Section 3. The perception of team balance, or the levels of the social network, is discussed in Section 6. The levels of social network analysis uncovers whether team members correctly perceive the relationships among their teammates. These initial findings open opportunities for future work on the role social network analysis can play in the analysis of collaborative learning.

1. Introduction

Real world engineering design problems are frequently solved by teams; therefore, as educators, we are required, both by ABET and common sense, to give students the skills and attitudes that enable them to work effectively in teams. One of the key skills is the ability to engage in collaborative learning with team members. In the process of acquiring the knowledge necessary to solve the design problem, collaborative learning gives students the opportunity to both learn from and to teach their peers. Developing the ability to engage in collaborative learning while solving engineering problems sets students on the path to life-long learning.

For students, the give and take with teammates is more intensely psychosocial than sitting in a classroom assimilating knowledge communicated by an instructor. Social networks naturally emerge from working in this peer-to-peer environment. These networks comprise relationships between the participants that include, for example, how well they know each other, how much they like each other, and how much they trust the information they get from each other. An important aspect of this network is not just the actual relationships, but the students' perceptions of the relationships. That is, team dynamics may depend on whether one *thinks* a team mate likes another rather than if they actually do.

The goal of this study was to explore the relationships among the social network of student teams, the team members' perception of their social network, and the teams' performance on an engineering design exercise. For the design exercise, we used a computerized version of Delta Design, a collaborative game that requires team members to share complex domain-specific knowledge in order to achieve a common goal.[1]

The factors correlated with the outcome of the study were:

- Accuracy of each team member's perception of the affective relationships between his/her teammates (*i.e.* subject senses whether teammate *i* likes, dislikes, or has neutral feelings towards teammate *j*).[2]
- Accuracy of each team member's perception of the perception that his/her teammates have of other teammates' relations.[3]
- *Structural balance* – a measure of the comfort level a person has working with his/her teammates, determined by that person's perceptions of the friendships (or lack of) of others in the group.[4]

2. Use of Social Network Analysis in Education Research

Information contained in a social network can be obtained by using Social Network Analysis (SNA). SNA is a set of theories and techniques used to examine the relations (*ties)* between entities (*nodes*) in a group in order to determine the structure of the group as a whole, the roles or positions of the group's members and the effect that the group structure has on its members.[5] An entity may be any object that exists as part of a larger social structure and interacts with the other entities in the group. This, for example, may be a team member in a design group, a design group within an organization, or a group of organizations, such as banks, that have interlocking directorates. Social networks can represent many different types of nodes and ties, such as the flow of money in a financial network, diplomacy in a network of countries, or friendship within a group of individuals.

The two primary streams of education research using SNA have been 1) to understand what affects the formation of relational ties in a given population, such as the students in a classroom and 2) to understand the influence that the social network has on outcomes. In the latter case, outcomes can be at the individual level, such as GPA or level of post-graduation income, or at the population level, such as graduation rates of retention in the STEM disciplines.[6]

One set of SNA techniques determines a group member's *centrality*.[7] Centrality measures can be used to determine the role that an entity plays in a network or predict where an entity falls in a formal or informal hierarchy. For example, Brewe, *et al.* used SNA to analyze the usage of a Physics Learning Center by a multidisciplinary mix of STEM students.[8] They were able to show that students who made greater use of the facility were more central in the informal social network that grew up around the Center.

SNA has also gained currency in the study of collaborative learning environment as a way for an instructor to assess students' participation in the learning/creating process. SNA allows instructors to identify participants' roles in problem solving groups and can provide a dynamic visualization of the interactions among the participants. In addition, SNA can serve to track the evolution and growth of social patterns and roles as they change over time.[9]

Krčadinac *et al.* studied logs collected during a collaborative learning exercise to determine the affective structure of students' interactions.[10] They generated a graphical representation based on the emotional tenor of the discussions with the goal of enabling instructors to step in when the collaborative task went off track, using appropriate organizational psychology methods.

3. Structural Balance and Team Problem Solving Outcomes

Paraphrased, Heider's theory of structural balance[4] states that the following rules must be followed in a system of three people or two people and an object, or the triad will be unbalanced:

> *The friend of my friend is my friend.*
> *The friend of my enemy is my enemy.*
> *The enemy of my friend is my enemy.*
> *The enemy of my enemy is my friend.*
>
> *Old Arab saying;* Reported by, among others, Rapoport[11]

While not the way Heider originally formulated the theory, the above set of rules state precisely the basic premise of structural balance.

Let us call the members of the network Ira (*i*), Jay (*j*), Kay (*k*), and Ella (***ℓ***). For example, suppose that Ira likes Jay and Kay, but perceives that Kay does not like Jay. These relationships are such that, "The enemy of my friend is my friend" instead of the balanced "The enemy of my friend is my enemy" so the triad is unbalanced. Ira will either try to influence Kay to like Jay ("the friend of my friend is my friend") or change his *perception* of Kay's feeling towards Jay, such that he comes to believe that Kay really likes Jay, or will decide that he does not like Kay after all. Any of these actions will balance the triad and restore Ira*'s* equanimity.

The original motivation for our study was to determine if balanced teams had better team performance than unbalanced teams. While a number of studies have shown that people prefer balanced to unbalanced situations, only one study has looked at whether the state of balance affects team problem-solving outcomes.[12] The problem solving task was: given a list of objects, chose the ones that will best enable the team to achieve a given task. The problem required the team members to reach a consensus on the best approach to solving a problem. With a sample size greater than 60 subjects, this study found a significant correlation between balance and problem-solving outcome.

4. Delta Design

Delta Design is a board game created by Bucciarelli to give students the experience of a complex engineering design task requiring cooperative behavior to succeed.[1] The task requires a team of four students, each with a different engineering role, to design a residence on the planet of DeltaP. DeltaP is a flat land with a skewed coordinate system (Figure 1), different units (Table 1) and complex interdependent constraints involving thermal, structural, construction and aesthetic requirements. In addition, gravity does not act vertically, but parallel to the plane and may change from 30^o to 150^o at any time. The possible board moves are: add or reposition a tile, change the color (temperature) of a tile and add or reposition the gate that keeps the Deltans (the inhabitants of DeltaP) from falling out of their home. Each team member plays one of four well-defined roles: Project Manager, Architect, Structural Engineer, and Thermal Engineer. Any team member can make any of the moves, but only one team member can move at a time. There is no preset order of play. Any move affects all the domains. A player making a move to improve e.g., the reactive forces on the home, may unkowningly cause the thermal requirements to be violated. The players must negotiate and share information about their constraints in order for the team to create a design that meets or exceeds all the requirements.

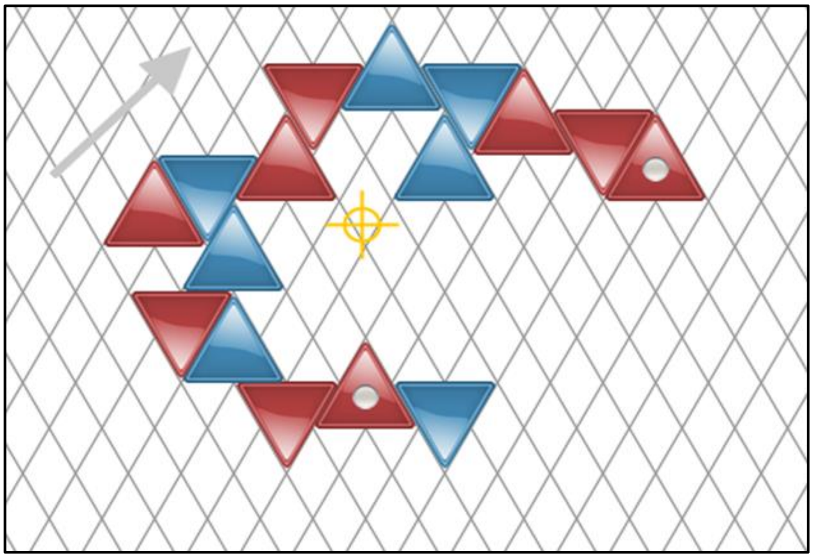

Figure 1. Example of plan view of a Deltan Residence. The triangles are building blocks. The arrow indicates the current direction of gravity.

Table 1. Deltan measurements

Measurement	**Unit**
Time	Wex (wx)
Distance	Lyn (ln)
Area	Quarter-delta (qd)
Heat	Deltan Thermal Unit (DTU)
Temperature	Degrees nin (^{o}Nn)
Force	Din (dn)
Moment	Lyn-din (ld)
Currency	Zwig (!)

The Delta Design board game has been implemented as a computerized game, so the computer now solves the equations and players are free to deal with issues inherent in collaborative design.[13] In addition, all of the communication between the team members occurs in a chat window so that the negotiations can be captured and analyzed. Each player sees detailed information on the requirements and computations for his/her role, but sees only a summary (a red, yellow or green light) of the status their teammates. To ensure that only one player can move at a time, players can lock the board for a fixed amount of time. “Who has the board” becomes a matter of negotiation.

A team's performance is determined by how closely the final design meets the specifications for each role. Each specification is given a normalized score that ranges from 0.0 to 2.0. A 1.0 means that the specification was met exactly, greater than one means that the specification was exceeded, while less than one means the specification was not met. Because the potential values of the specifications and the difficulty of meeting each specification are not equally distributed among the teammates, we assume that each player contributed equally. Other factors can be scored, or at least taken into account. For instance, how long each player had the board locked is known, as is how often a player spoke up to make a suggestion. Between the detailed play history and the chat window, a great deal of data can be collected for later analysis.

5. Subjects

The subjects in the study were students in an inter-departmental capstone course on rapid prototyping of computer systems. An important aspect of the class is that all of the students work on a single large design project. At the beginning of the semester, students are given the specifications for the desired outcome of the system, at which point the students assign themselves to functional teams of four to six individuals. Each team is responsible for one aspect of the system (e.g., operating system, hardware/software integration). The class always delivers a functional prototype to their client at the end of the semester. The course is structured collaboratively, allowing the students to learn with and from each other. The instructors take the role of advisors, keeping the students on track, and guiding them when needed rather than lecturing to them.

Of the 37 students in the Spring 2014 class, 36 were assigned to nine teams for the Delta Design exercise. Of those, 32 were present for the exercise, decreasing the number of teams to eight. Those present were from the Information Networking Institute (3), the Electrical and Computer Engineering Department (24), the Human-Computer Interaction Institute (4), and the School of Computer Science (1). The group comprised one junior, six seniors, one fifth-year student, and 24 master's students. There were 23 males and 9 females. One team's instance of Delta Design froze during the exercise, and their scores had to be treated as missing data in certain analyses. The method for constructing the teams is discussed in Section 7.

To reveal the social network, the students filled out a questionnaire, embedded in the Kiva collaboration tool,[14] which the students used for all class communications. Figure 2 shows a screen dump of the questionnaire in which each student was presented with the name and picture of each of the other students in the class. The questionnaire asked whether they knew the person, how they felt about the person and how much they trusted the information they got from the person. If the answer to the first question was negative, the questionnaire immediately moved to the next person.

The sociograms in Figures 3 and 4 show two subsets of the social networks from the class. The nodes are the students in the design class and the ties are friendship ties. In Figure 3, the ties represent strong friendship (greatly like) relationships. If a tie has an arrow on each end, each student reported a friendship with the other. If the tie has an arrow on only one end, it means only one student reported a friendship with the other, so the friendship is not reciprocated. In Figure 4, the ties represent strong dislike.

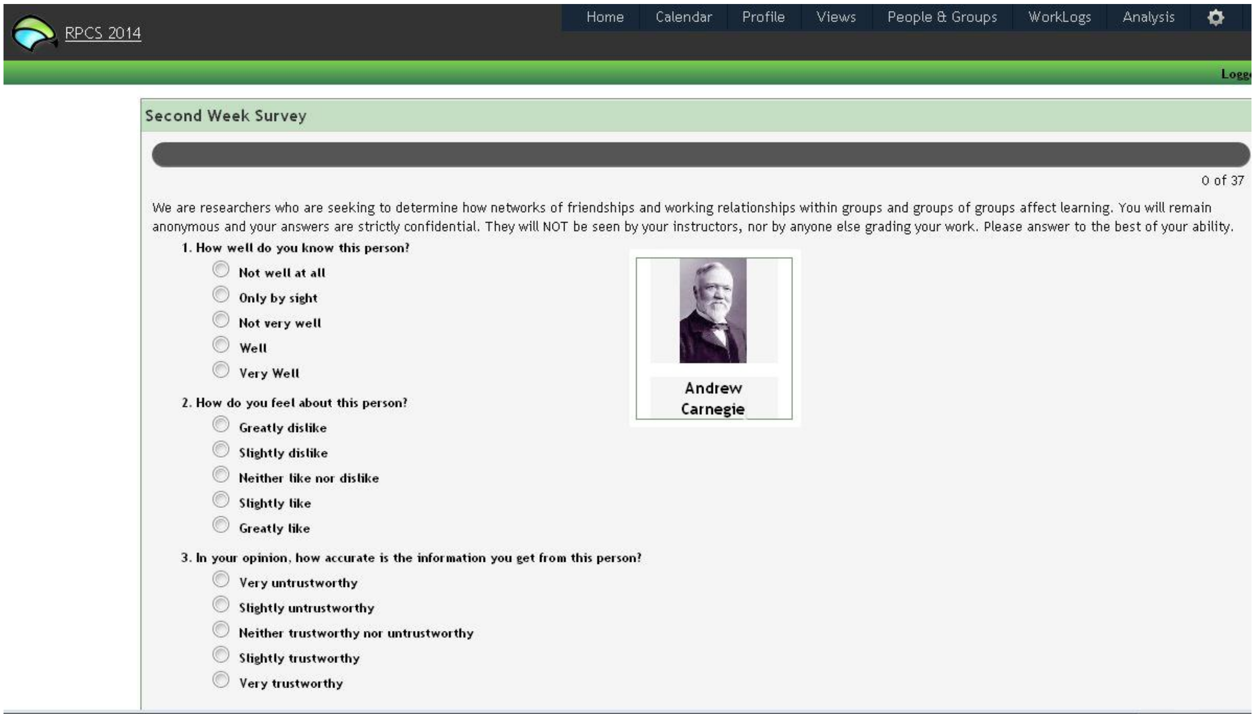

Figure 2. Computerized social network questionnaire

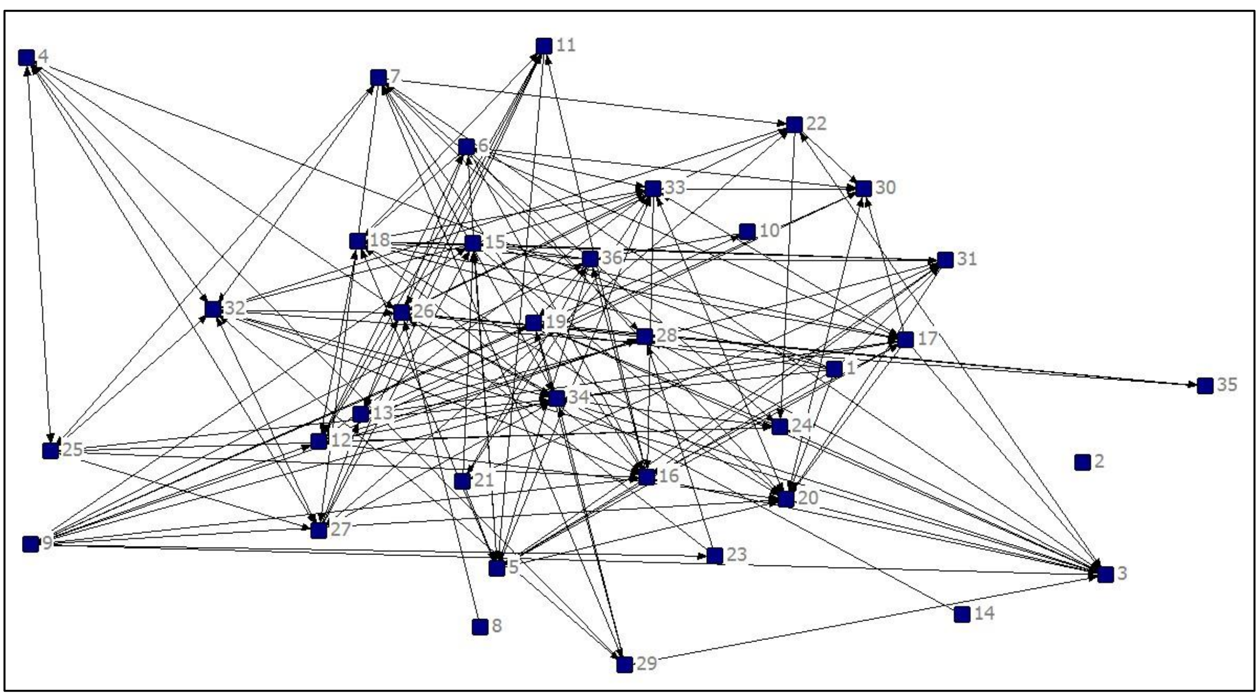

Figure 3. Subset of the class social network showing “Greatly Like” ties

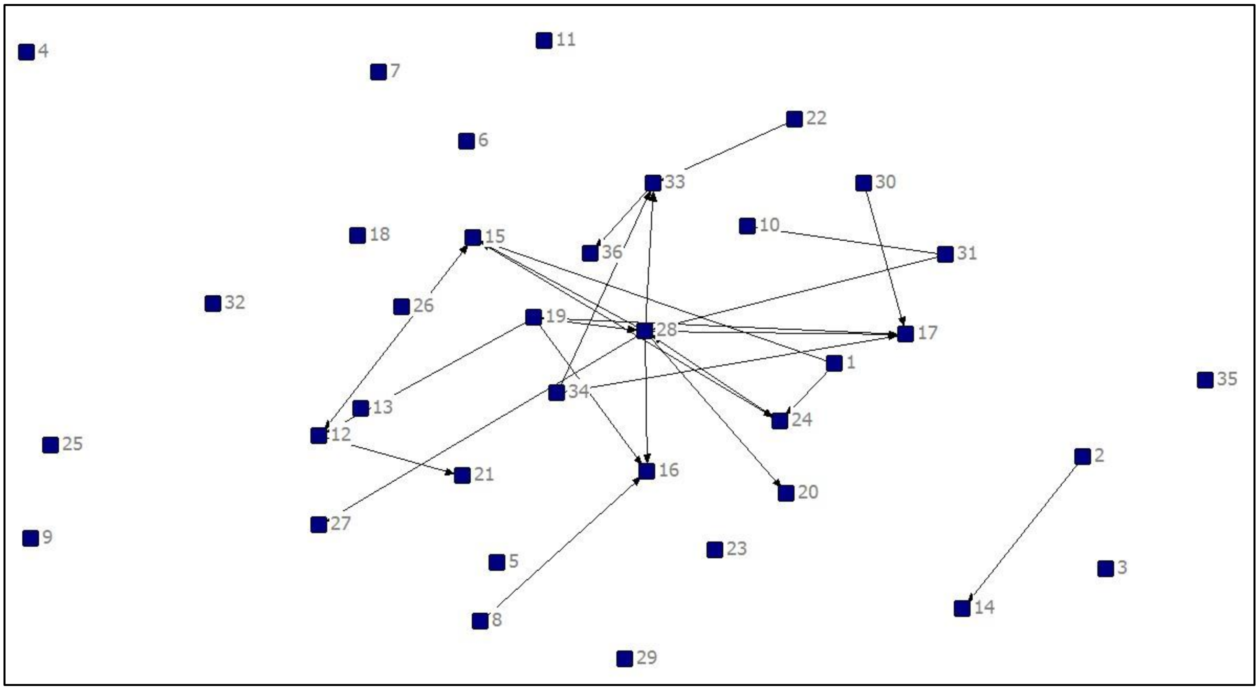

Figure 4. Subset of the class social network showing "Greatly Dislike" ties

The information in the sociogram may also be represented in an adjacency matrix, a two-dimensional matrix in which the rows and columns are the students and the elements are the strength of the relationship. Table 2 shows a sample of the full 36 by 36 matrix, selected to show the range of relationships among the students.

Table 2. Submatrix of the social network adjacency matrix; The row and column numbers are student identifiers; -2 is greatly dislike; 2 is greatly like

	12	13	14	15	16	17	18	19	20	21	22	23
12	-	1	1	-2	-1	2	2	1	2	-2	0	1
13	-1	-	0	-1	1	1	0	0	1	-1	0	0
14	0	0	-	0	-1	0	0	0	0	0	0	0
15	-2	1	1	-	-1	2	2	1	2	-1	1	0
16	1	0	-1	-1	-	1	2	0	1	1	0	0
17	2	2	0	1	2	-	2	0	2	-1	0	-1
18	2	1	0	1	2	2	-	0	2	0	0	0
19	-2	0	1	1	-2	-2	-1	-	-1	0	0	0
20	2	0	-1	0	-1	1	2	1	-	-1	0	0
21	-1	0	0	2	-1	0	-1	0	1	-	1	0
22	1	0	0	-1	1	-1	0	1	0	1	-	1
23	0	-1	0	0	-1	0	1	1	0	0	1	-

6. Levels of Social Network Analysis

Krackhardt identifies five levels of SNA:[15]

Level Zero refers to the attributes of the network itself[1].

Level I refers to the attributes of the entities in the network. In the case of students, these attributes could be, gender, age, grade level, GPA, etc.

Level II refers to the presence of a tie and its value (if any) between two entities. In an advice network this might be, "Ira gives advice to Jay 3 times a week." In a friendship network this might be: "Jay greatly likes Kay" (+2), "Jay slightly dislikes Kay" (-1), or "Jay is indifferent towards Kay" (0). Most SNA research is on Level II.

Level III refers to what one person perceives the ties between two other people to be. For example, Ira perceives that Kay does not like Jay.

Level IV refers to one person's perception of how another person perceives the ties between two other people. For example, Ella perceives that Ira perceives that Kay does not like Jay.

This paper focuses on Level III and Level IV perceptions. The Thomas Theorem expresses the usefulness of these levels.[16] The theorem states: "If men define … situations as real, they are real in their consequences." That is, in some situations, how people *perceive* relationships in their social networks is as, or even more, important than the actual relationships for the prediction of roles and behavior.

6.1 Level II

The Level II ties between members of a social network are represented by a two-dimensional adjacency matrix $\boldsymbol{T}_{i,j}$, where i is the "sender" and j is the "receiver." For example, in a friendship network, $\boldsymbol{T}_{i,j} = 2$ if Ira reports he greatly likes Jay. $\boldsymbol{T}$ is the two-dimensional *Truth Matrix* which contains, e.g. Ira's answer to the question: "Do you: greatly like, somewhat like, are indifferent to, somewhat dislike, greatly dislike Jay?" Table 2 is an example of a truth table.

6.2 Level III

Level III accuracy refers to whether or not a person correctly perceives how another feels about a third. (E.g., Kay correctly perceives that Ira likes Jay.) Since people show their feelings through various types of body language, including voice,[17] it is reasonable to expect that if Kay sees Ira and Jay interacting, she would be able to determine what their feelings are for each other.

Krackhardt calls the set of perceptions that an individual has about the feelings that his/her peers have towards each other a *Cognitive Social Structure* (CSS).[2] In a small-scale study (N = 26), he

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[1] These attributes include the network's diameter (the distance between the two nodes that are the farthest apart), shape (e.g. kite, star), and density (the ratio of nodes that are connected to the maximum number of possible connections. The latter is always the total number of nodes – 1.

demonstrated that the beliefs that people have of how powerful an individual is in an organization is positively correlated with the accuracy of that individual's CSS of his/her advice network.[15] However, the accuracy of the individual's CSS of his/her friendship network did not predict how others perceived the individual's place in the organizations' formal hierarchy.

A Level III CSS is represented by a three-dimensional matrix $\boldsymbol{R}_{i,j,k}$ where *k* is the perceiver, *i* is the sender and *j* is the receiver (Kay perceives that Ira likes Jay). In order to perform various analyses, this matrix can be transformed into two-dimensional matrices in three different ways. These forms are called *slice, locally aggregated structure,* and *consensus structure*.[2] In this paper, only the slice is discussed.

The *k*th slice of $\boldsymbol{R}_{i,j,k,}$ is the two-dimensional matrix $\boldsymbol{R}_{i,j}$ where Kay is the perceiver, Ira is the sender and Jay is the receiver. For a friendship network, the *i,j,k* cell of the matrix contains Kay's perception of the friendship bond between Ira and Jay. That is, the *k*th slice of $\boldsymbol{R}_{i,j,k,}$ is Kay's perception matrix. For this study, the cells contain the strength of the friendship from Kay's responses to: "Do you believe that Ira: greatly likes, somewhat likes, is indifferent to, somewhat dislikes, greatly dislikes Jay?" The values range from -2 to 2.

The *accuracy* of Kay's perceptions is found by comparing the entries in Kay's perception matrix with the Level II *Truth matrix*, which contains the actual friendship links between the members of the network.

6.3 Level IV

The Level IV data is the 4-dimensional matrix $\boldsymbol{P}_{i,,j,k,\ell}$ containing ℓ's perceptions of *k*'s perceptions of how *i* feels about *j*. If we relabel our generic team of four people using specific numbers rather than generic letters, we have Ira (1), Jay (2), Kay (3) and Ella (4), then the cell $\boldsymbol{P}_{1234}$ contains Ella's perception of Kay's perception of how Ira feels about Jay. To create Level IV friendship network, Ella is asked for her perception of the following:

Kay's perception of Ira's feelings of friendship towards Jay (P_{1234})
Kay's perception of Ira's feelings towards Ella herself (P_{1434})
Kay's perception of Ira's feelings towards Kay herself (P_{1334})
Kay's perception of Jay's feelings towards Ira (P_{2134})
Kay's perception of Jay's feelings towards Ella herself (P_{2434})
Kay's perception of Jay's feelings towards herself (P_{2334})
Kay's perception of Ella's feelings towards Ira (P_{4134})
Kay's perception of Ella's feelings towards Jay (P_{4234})
Kay's perception of Ella's feelings towards herself (P_{4434})

Since there are 4^N permutations of a series of four, and, in our case, N = 4 (the number of members in a group), there are 256 possible combinations. Of the 256 permutations, 64 have the same first two digits. For our purposes, whether Ella perceives that Kay thinks that Ira likes Ira is not relevant. The remaining 192 instances collapse into 8 *equivalence classes*, each with twenty-four unique cases. For example, in one class all four digits are unique. An example is 1234: Ella perceives that Kay perceives that Ira likes Jay. Another example of the class is 3241: Ira perceives that Ella perceives that Kay likes Jay.

In another equivalence class, the first and last digits are the same, and the second and third digits are the same but different from the first and last, e.g. 1221: Ira perceives that Jay perceives that Ira likes Jay. Another example of this class is 3113: Kay perceives that Ira perceives that Kay likes Ira. Table 3 is the list of the classes and their rules. The interpretations are for perceptions of liking links.

Table 3. Equivalence Classes

Class	**Name**	**Pattern;** interpretation for liking links
4144	Level II	$i = k, \ell;\ i \neq j$
		ℓ perceives that ℓ perceives that ℓ likes j. *E.g.*, Ella likes Jay, which is a Level II observation.
1444	Level III	$i \neq j, k;\ \ell; j = k, \ell$
		ℓ perceives that ℓ perceives that i likes ℓ. *E.g.*, Ella perceives that Ira likes her, which is a Level III observation.
1244	Level III	$i \neq j, k, \ell;\ j \neq k;\ k = \ell$
		ℓ perceives that ℓ perceives that i likes j. *E.g.*, Ella perceives that Ira likes Jay, which is a Level III observation.
4114	"Game Player"	$i = \ell;\ i \neq j; k;\ j = k$
		ℓ perceives that i perceives that ℓ likes i. *E.g.*, Ella perceives that others know that she likes them.
1224	"Matchmaker"	$i \neq j, k, \ell;\ j = k;\ k \neq \ell$
		ℓ perceives that j perceives that i likes j. *E.g.*, Ella perceives that other people know when someone else likes them.
4234	"Game Theorist"	$i = \ell;\ i \neq j, k;\ j \neq k$
		ℓ perceives that k perceives that ℓ likes j. *E.g.*, Ella perceives when someone else knows that she likes another person.
1434	"Narcissist"	$i \neq j, k;\ \ell; j = \ell;\ j \neq \ell.$
		ℓ perceives that k perceives that i likes ℓ. *E.g.*, Ella perceives that others perceive that others like her
1234	"Sophisticate"	$i \neq j, k, \ell;\ j \neq k, \ell;\ k \neq \ell.$
		ℓ perceives that k perceives that i likes j. *E.g.*, Ella perceives that Kay perceives that Ira likes Jay.

The Level IV data is compared to Level III data to determine the accuracy of the Level IV perceptions. That is, does Ella correctly perceive what Kay perceives about how Ira feels about Jay? Note that Ella acts on her *perception* of Kay's perception, so the correctness of Kay's perception does not affect Ella's actions.

While the differences among the equivalence classes is subtle, one of the findings discussed in the Results and Conclusions sections is that the accuracy of perception for each class differ from each other significantly,

6.4 Accuracy

To determine the degree to which a person's perceptions match the actual relationships, we construct an *Accuracy Matrix*, ***A***, which contains the number of times a team member correctly/incorrectly perceives a relationship (Table 4). In Table 4, the diagonals contain the number of times that perceptions match the true relationship; the off-diagonals contain the number of times that the relationships are misperceived. For example, a_{31} contains the number of times that a student perceives that two teammates dislike one another when in fact they like one another.

Table 4. Accuracy Table

		Truth		
		like	indifferent	dislike
Perception	like	a_{11}	a_{12}	a_{13}
	indifferent	a_{21}	a_{22}	a_{23}
	dislike	a_{31}	a_{32}	a_{33}

To compute the *accuracy index*, *S*, we use a modification of the equation, s_9, in a 1986 paper by Gower and Legendre.[18] The sum of the incorrect perceptions is subtracted from the sum of the correct perceptions, and the result is divided by the sum of all of the perceptions, thus:

$$S = \frac{\sum_{i=j}^{n} a_{ij} - \sum_{i \neq j}^{n} a_{ij}}{\sum a_{ij}}$$

where *S* = the accuracy index. In this case, *n* is 3 because we have combined like and greatly like as well as combining dislike and greatly dislike.

7. The Delta Design Study

The four members of each Delta Design team were selected based on the structural balance index derived from the survey. As stated in Section 3, structural balance is an SNA construct that predicts how comfortable any three people (a triad) in a group feel given their perceptions of the relations between the members. The structural balance index is the ratio of the balanced triads to the total number of triads making up the team. Since a team of four comprises four triads, this index can take on one of the values of 0.0, 0.25, 0.5, 0.75, and 1.00.

The study was performed in a computer cluster. The instructions were distributed the day before, with each player getting the unique set that pertained to his or her role. To prevent pre-game collusion, it was not until the players were seated in the computer cluster that they learned who was on their team. The players were seated such that team members were far apart, and players with the same role were also seated apart. The full names of the students appeared in the chat window so the students knew who was on their team. The students were instructed not to communicate between teams, but only with their teammates via the chat window. The game was played for one class period (80 minutes). Every state of the game and all of the chat conversations were captured in a database on the server side for later analysis.

At the end of the semester, the students also filled out a Level IV questionnaire for their Delta Design team. This questionnaire asked them only about their perceptions of the likes and dislikes for the other three members of their Delta Design team.

8. Results

The data collected in this study were ties of acquaintanceship, friendship, and trust. Only the friendship ties are presented in this paper. In this study, we were interested in determining the accuracy with which team members perceived their teammates feelings towards each other and how the balance index of a team affected the teams' performance on the Delta Design exercise.

There were originally 8 teams in the study. The data on one team had to be discarded because their instance of the game froze, and they were unable to complete the exercise. Another team was eliminated from the analysis because every team member had a perfect Level IV accuracy index (1.0). We believe that this level of accuracy, along with the level of agreement of their responses was highly unlikely without the possibility of collusion. (The survey was administered online with the students responding outside of class). If this result, which runs counter to the general finding, is included in the analysis, the results are similar to those reported below, but do not rise to a level of significance.

Table 5 presents the raw scores for the accuracy of Level III, the accuracy of Level IV, the balance indices of the teams, and the dependent variable, which is the team score on the Delta Design exercise. The correlations are shown in Table 6. Table 7 contains the variables' descriptive statistics.

Table 5. Accuracy, balance, and team scores

Accuracy Level III	Accuracy Level IV	Team Balance	Delta Design Scores
-0.056	0.103	1.00	10.2
-0.444	-0.154	0.00	10.0
0.333	0.244	0.25	9.7
0.167	0.692	0.00	9.6
-0.278	-0.077	0.50	9.4
0.556	0.628	0.00	9.2
-0.500	0.654	0.00	8.7

Table 6. Correlations between Balance, SNA Levels and Score

	Balance	p-value	Level III	p-value	Level IV	p-value
Balance	1					
Level III	-0.27743	0.189351	1			
Level IV	-0.31089	0.139225	0.36921	0.075809	1	
Score	0.51029	0.010843	-0.34642	0.097254	-0.37581	0.070326

Table 7. Descriptive statistics

	Level III	Level IV	Balance	Results
Mean	-0.032	0.299	0.250	9.543
Std. Dev.	0.402	0.360	0.382	0.503
Range	1.056	0.846	1.000	1.500
Minimum	-0.500	-0.154	0.000	8.700
Maximum	0.556	0.692	1.000	10.200

Table 8 contains the average accuracy index of the 24 instances of each of the eight classes. A positive index indicates that there were more correct than incorrect perceptions. A negative index indicates that there were more incorrect than correct perceptions. An index of 1.0 indicates that all of the perceptions were correct. An index of 0.0 indicates that there were as many incorrect as correct perceptions. An index of -1.0 indicates that all of the perceptions were incorrect.

The highest score was the 1.000 of the Level II class. This is true by definition, as the Level II class is simply "Ira likes (dislikes, is indifferent to) Jay." If the subjects were honest in their responses, this statement is irrefutable and represents the truth against which the Level III responses are measured." The highest index representing perceptions *per se* is that of the "narcissist." The lowest indices are those of the Level III classes. Both indices are either equal to or near 0.0, which indicates that as many of their perceptions were incorrect as correct.

Table 8. Summary of equivalence classes' accuracy scores.

Class Pattern	Accuracy Score	Level
4144	1.000	II
1444	0.000	III
1244	0.010	III
4114	0.271	IV
1224	0.208	IV
4234	0.292	IV
1434	0.427	IV
1234	0.302	IV

Notes: N = 7, M = 0.314, SD = 0.313. Maximum range of score = -1 to 1.

8.1 Balance

Balance and team score are correlated, which is as predicted. Theoretically, if there is no affective tension among the team members, the individuals' energy and attention can be focused on solving the problem rather than alleviating personal discomfort.

8.2 Levels III and IV

Level III accuracy is correlated with Level IV accuracy, which makes sense. If a person is perceptive when it comes to observing the affect between teammates, it is reasonable that they are sensitive to affect at one remove.

Interestingly, Level III and Level IV are negatively correlated with team scores and with team balance. While the correlations are not highly significant, this is a counter intuitive result which requires more study

9. Conclusions and Future Work

The correlation between balance and team scores agrees with the study done by Civettini.[12] We have repeated the Delta Design exercise with a class whose network has more affective ties because the students have been in classes together for over two years. Hence, there were fewer null ties ("I do not know this individual" or "I neither like nor dislike this individual), making the balance between like and dislike ties more evenly distributed and the subsequent network is less sparse than that of study being reported on. We are still analyzing the data from the current study.

We have a particular interest in looking more closely at the attributes of the equivalence classes. Their existence was unexpected and we would like to determine if the differences between the accuracy scores are artifacts, due to chance, or have a deeper meaning.

We plan to analyze the chat logs using linguistic and content analysis to determine tenor of the team's interaction with each other. Understanding how balance affects the conversation would further the understanding of the team's dynamics and make greater use of the data that Delta Design produces.

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