An Examination of Team Diversity and Its Impact on Design

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Abstract - **First year engineering courses often contain design projects of various sorts, ranging from computer programming to physical design. Because their previous design experiences are somewhat limited (as are their theoretical analysis abilities), they resort to imitation of existing designs. The proposed paper examines a multi-stage series of designs performed by first year engineering students at a large Southwestern Institution. We adhere to the operational definition provided by Daly, Mosyjowski, and Seifert [1] in which creativity is described as a "type of novel thinking, where people redefine problems, see gaps in knowledge, generate ideas, analyze ideas, and take reasonable risks in idea development" (p. 418). We also adhere to the cognitive processes in creativity as defined by Mumford, Mobley, Uhlman, Reiter-Palmon and Doares [2] in Daly et al. [1], in which a focus on thinking pattern through specific stages in the creative process is used. These include "problem finding, information gathering, information organization, conceptual combination, idea generation, idea evaluation, implementation planning, and solution monitoring" (p. 410). We analyzed projects in the first engineering program at a large Southwestern Institution as well as survey information regarding the generation of these projects in order to examine the relationships between creativity, team diversity (gender and ethnic), design complexity and structure, and information sources. These approaches allow us to quantify information sharing between teams and the use of information sources by making use network relationships and their metrics. Social network analysis methodologies have long been used to examine the relationships between information sources, such as authorship [3, 4], political book networks [5], and discipline relationships in technology and engineering [6]. Specifically, we will use a variety of directed flow centrality and ego network analyses. In addition, networks combining team information exchange and other information sources will be described and researched.**

Index Terms – Social Network Analysis, Gender Diversity, Design Teams,

INTRODUCTION

This paper examines diversity within student teams and its impact on student performance and interactions between teams. Specifically, it examines three types of diversity, (sex, ethnic, and home academic institution) within a first year engineering course. *Fundamentals of Engineering II* is a large (2,492 student) multi-section course taught by multiple instructors at a major southwestern university. The course section sizes ranged from 20 to 100. This paper examines a subset of those classes consisting of seven sections divided into five classes. Multiple sections existed in two of the classes under examination to administratively manage classes containing students from another institution. This course requires the completion of a significant, semester-long project, in this case a marble sorter. As part of the course, the students were divided into teams of 3 – 4 students, with the later stages of the project completed by task-forces consisting of 3 – 5 teams.

Project Description

The overall project was the creation of a marble sorting and delivery device. In the project, students were asked to construct a device to sort marbles based on size, color, and material. This paper examines the interactions between teams during the first stage of the multistage project. In this stage individual teams of 3-4 students were required to create a receiver for up to 50 assorted marbles and then deliver them in a steam of individual marbles. Success in this assignment is critical to the performance of the later stages and requires the development of an apparatus that is highly resistant to the plugging problems common in particle delivery systems. As part of this assignment students were provided a video of one potential solution on the course website and asked to perform a patent search that identified three alternate solutions. The students were also encouraged to perform other types of research. Two types of materials were provided Lego Mindstorms Kits and tongue depressors (typically used to create marble storage elements and channels for marbles). In addition, the students were allowed to purchase or find additional materials for their design having a maximum aggregate value of $40.00.

Diversity

Diversity is a challenging term to define within an academic setting, since there are a wide variety of possible traits that can be evaluated. Some of these include sex, ethnicity, age, intended major, and economic status. For the purpose of this paper, diversity within a team will be defined as the presence of member of more than one of the sex of student within a team.

In engineering, gender diversity has often been an indicator of the addition of women to a team, rather than the converse. This diversity brings with it the potential for alternative viewpoints in design. As noted by Udén in 2002, "women are often regarded as having the potential to bring change to technology. Ewa Gunnarsson, based on her studies of qualifications in industry, has proposed that women bring a caring rationality to technology. … The most well known examples however, where women are presented as bringing alternatives or contrasts to a dominating practice, are not retrieved from technology studies but studies such as… genealogy and… of the biological knowledge among women farmers in India." [7]

METHODS

This paper examines the traits and interrelationships between teams of those students. The network of team relationships examined in this paper was gathered at an early stage of the project, prior to taskforce-based project assignments. The student population traits were gathered from a combination of an in-class survey and the university's student databases.

Network Metrics

Network metrics are the mathematical characteristics that describe the network. Since the directionality of the ties between nodes was not always clear, interactions between teams were assumed to be bidirectional. Hence, the adjacency matrix was symmetrized prior to analysis. Two types of analyses were performed. In the first, the overall characteristics were assessed. In the second, the network traits of individual teams were examined. Those used in this research are: geodesic distance, degree, and homophily. It must be noted that all values quoted have been normalized.

Overall network centrality was measured as degree centrality, betweenness, and closeness and the overall network size was characterized as the frequency of components of various sizes, average centrality, and the average geodesic distance. The average distance was the average geodesic distance amongst pairs and the maximum diameter was length of the longest geodesic. Since the network was discontinuous, the average distance and the maximum diameter were assessed only for reachable nodes [8].

Degree centrality is a measure of direct connectivity to other nodes or the number of connections a node has with other nodes [9, 10]. Degree centrality operates on the presumption that a team that has a high degree centrality is heavily involved and has the potential for high communicatively, while team with low access to information. [11] It is the most basic element of a network graph, which can be used to characterize a node or the whole network using the average degree [12].

Betweenness centrality is a measure of a team's strategic location on the communication paths linking other teams. It operates on the presumption that a team in such a position can influence the group by providing access to, withholding, or distorting information in transmission. [11]

Closeness centrality of a point was measured as the summing the geodesic distances from that point to all other points in the graph. It should be noted that closeness is a measure of point decentrality or inverse centrality, since it increases as the nodes are farther apart [11].

Homophily is the tendency of individuals to group together based on a common factor [13, 14]. The sociograms were examined to identify regions of homophily based on the presence or absence of diversity homophily. Homophily of student traits within the networks was evaluated as the E-I index [15]. The E-I index is computed as:

$$E - I\ Index = \frac{EL - IL}{EL + IL}$$

where: EL is the number of external links and IL is the number of internal links. The possible scores for this index range from -1.0 (all links to alters are internal to trait group's members) to +1.0 (all links to alters are external to the trait group's members). If the links are divided equally,

Statistical Analysis of Data

The social network analyses were performed using UCINET version 6.575 [8] with Netdraw version 2.152 [16] used for network visualization and preliminary analyses. It should be noted that the nature of network data violates the independence requirements for standard statistical analyses [17]. Therefore, statistical analyses involving network traits were performed by permutation within UCINET.

RESULTS

Overall Network Description

The network was fragmented into a 40 clusters ranging in size from 1 team to 22 teams. Their distribution is shown in the adjacent bar graph.

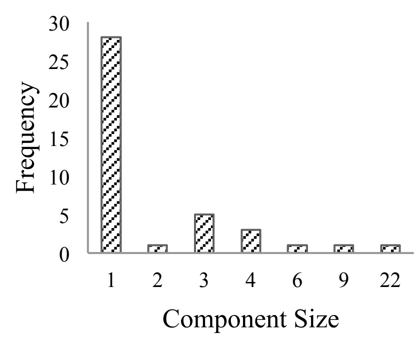

FIGURE 1.
DISTRIBUTION OF THE SIZES FOR THE NETWORK'S COMPONENTS

Only 28 of the teams (approximately 30%) worked as isolated teams, while the remainder collaborated with other teams. It should be noted that inter-team information sharing was not prohibited by the instructors and was not considered "academic dishonesty" within the course. A sociogram of the team network (omitting isolated teams for clarity) is shown below. This sociogram demonstrates significant homophily by class. This was expected, since no efforts were made by the instructors to promote inter-class collaboration.

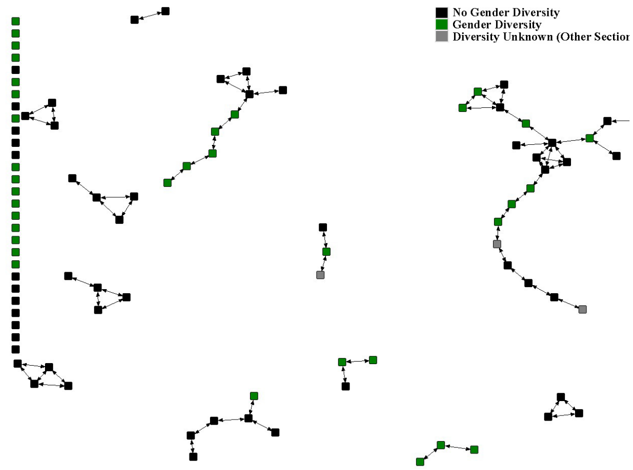

FIGURE 2.
A SOCIOGRAM OF THE INTERACTING TEAMS. TEAMS ARE INDICATED BY COLORED SQUARES AND INTERACTIONS ARE INDICATED BY THE DOUBLE-HEADED ARROWS. ISOLATED TEAMS HAVE BEEN REMOVED FOR CLARITY. THE PRESENCE (■) OR ABSENCE (■) OF GENDER DIVERSITY IS INDICATED. OF SPECIAL NOTE ARE THE ■ SQUARES THAT INDICATE TEAMS OUTSIDE THE SECTIONS INCLUDED IN THE STUDY.

When the Network was examined analytically for gender diversity-base homophily, the expected value for the E – I index was 0.022. However, the computed value was -0.242 (with a standard deviation of ±0.123) this indicates a significantly higher tendency (p = 0.024) for the gender diverse teams to interact with other gender diverse teams. This is consistent with other evaluations of gender-based homophily based on the interactions of individuals in academia [3, 14, 18]. Interestingly, it has been noted [19], that homophily between individuals has potential to enhance information transfer, particularly in complex topics, where trust is important. One possibility, for the success of more diverse teams is their ability to harness homophily of multiple types to provide cross-fertilization of ideas.

It should be noted that the teams used other sources in gathering ideas for their designs. The primary resource, as expected, was internet-based research with only one team using the library. Within the Internet category, three sources predominated; the course eCampus website (30%), YouTube™ (30%), and the patent office (33%).

TABLE I
OVERALL NETWORK DESCRIPTIVE MEASURES (N = 94 TEAMS).

Network Characteristic	Mean	Standard Deviation	Standard Error of the Mean
Degree	3.39	3.75	±0.39
Betweeness	93.35	225.67	±23.28
Closeness	572.79	219.74	±22.66
Geodesic Distance	4.1	2.9	±0.3

DISCUSSION

Utilizing Social Networks Analysis [17], we conducted one-tailed and two-tailed T tests in the following sets of data: (1) Gender diverse teams and non-provided materials (the provided materials were LEGOs and tongue depressors); (2) Gender non-diverse teams and relative more use of provided materials; (3) Gender diverse teams and more use of found materials (the meaning of found is found at home or dorm); (4) Gender diverse teams and purchased items; (5) Gender diverse teams and use of tongue depressors; (6) Gender diverse teams and use of LEGOs; (7) Gender diverse teams and team functionality (versus team dysfunctionality); (8) Gender diverse teams and the design process grade; (9) Gender diverse teams and design product grade; (10) Gender diverse teams and more hours spent on subtasks; (11) Gender diverse teams and use of external resources; (12) Gender diverse teams and grade given to final report; (13) Gender diverse teams and grades given to subtasks.

One potential indicator of this ability to "think outside the box" is increased use of non-provided materials in the development of the student projects. Establishing the statistical significance at a level of 0.05, we found significant differences in: (1) Gender diverse teams and non-provided materials (the provided materials were LEGOs and tongue depressors), at the two-tailed and one-tailed tests; (2) Gender non-diverse teams and relative more use of provided materials, at the two-tailed test; (3) Gender diverse teams and more use of found materials (the meaning of found is found at home or dorm), at the two tailed and one-tailed tests; (10) Gender diverse teams and hours spent on subtasks at the one-tailed test; and (12) Gender diverse teams and grade given to final report at the two-tailed test.

These results provide a preliminary understanding that gender diverse teams make more use of non-provided materials, make more use of found materials, spent more hours on subtasks, and grade differently their final report than their non-diverse counterparts.

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