Analysis of Online Collaboration among Undergraduate Engineering Technology Students in Green Energy Manufacturing

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Network analysis of undergraduate engineering interactions in an informal learning environment

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Abstract

This study uses social network analysis to examine the patterns of student interactions in an online site designed to join students within undergraduate engineering technology programs at two universities. The site was developed with Google Groups to provide students the opportunity to discuss, share, and learn both from and with one another on topics related to green energy manufacturing. The study demonstrates that the online site supports interaction among the undergraduate students. In particular, the networks formed by these interactions were sparse; online students shared course-related advice and information across the sites as a whole and were selective with those whom they sought out for support, information, or guidance. This study has implications for future research to determine why students chose to use the site to interact with their peers and what these interactions provided them. Such data could inform the ways the site helped support students both in their advancement in the program, and could be useful in assisting future development of such sites and similar learning spaces.

Keywords: Online Learning, engineering technology, green energy manufacturing, Social Network Analysis, Undergraduates, UCINET

Background

For several years, the engineering departments of a northeastern, private university and southwestern, public university have collaborated on green energy manufacturing research and education. One mode of engagement between the undergraduate students at both universities has been an online social media platform designed to enable students to share their learning experience. Previously, such interactions were researched using Facebook (Ruane, Chiou, &

Tseng (2015). The conclusions from that previous study are extremely relevant to the results of this study. Both studies centered around online discussion among the undergraduate students who were simultaneously taking a course on green energy manufacturing. Green Energy manufacturing focuses on the study of environmental issues in manufacturing and industrial resources to reduce the environmental impact of their produced products and services. Green Energy manufacturing is an emerging field and is also a sustainable model for modern manufacturing industries. Sustainable green manufacturing encompasses the design of manufacturing processes to provide energy conservation, pollution prevention or reduction, and increased health and safety for communities, employees, and consumers (Chiou, Tseng, Ertekin, & Carr, 2013).

For the purpose of this study, we chose to use Google Groups as the platform to engage students and provide the opportunity to discuss, share, and learn both from and with one another on topics related to green energy manufacturing. To analyze the patterns of interactions between the group members, we used UCINET, a software package for social network data analysis.

Introduction

Social network analysis research of international collaboration in academia has shown the United States to be "consistently the most active and has a central role in international collaborations" (Guo, Zhang, & Guo, 2016, p. 508). At the same time online discussion spaces for courses has been growing in popularity across science and humanities disciplines. Having students from separate regions and universities use discussion spaces while they take analogous classes is the logical step in preparing students to approach international collaborations in research. As discussion boards gain popularity, there has been increasing research to maximize the learning of these communities. Research literature indicates that online learning discussions often fail to truly engage the students in productive dialogue (Wang & Chen, 2008).

For successful online learning communities, there must be three phases of cognition: triggering, exploration, and integration (Wang & Chen, 2008). The triggering phase is when a student is first prompted to action; they read the discussion topic and post their initial answer, questions, and/or questions on the topic (Wang & Chen, 2008). The exploration phase is when a student is prompted to explore the topic further by the responses they read that other students wrote in the triggering phase (Wang & Chen, 2008). This includes doing further research on a topic in order to support an argument being made against another student's post or exploring other research because a student's attention was brought to another aspect of the topic by another student's initial post. The final phase is the most important and is when a student integrates what s/he learned from discussion with other students (Wang & Chen, 2008). This would typically be seen in a post later in the discussion after there has been enough discussion for students to process the new perspectives and assimilate them to their understanding. The guidelines that the online learning coordinator provides to encourage meaningful participation in the discussion can be categorized as promoting any combination of the three phases: triggering, exploration, and integration (Wang & Chen, 2008).

Google Groups Platform

Green energy manufacturing students at the selected universities were given the opportunity and encouragement to discuss their coursework on a Google Group page. The rules used in this discussion board mirror the standard rules given by professors using online discussion boards. They are a set start date, a set due date, and a minimum number of posts. The online learning coordinator posted a topic each week with questions for the students to answer. This sets the start date. The students were asked to respond to the prompt in one post and reply to any other post at any other student that had posted to the topic. Their reply could be directed at any type of post that another student wrote, either another directed post or a general response one.

The purpose of this study is to understand the ways that students interacted and determine what these interactions indicate at two different universities in different parts of the United States in an online Google Group developed as an informal online learning environment. To pursue this research, a Google Group was developed and to provide a purposeful and relevant sampling. The students who participated in the Google Group were completing courses in Green Energy Manufacturing at the junior level of study with majors consisting of Industrial Engineering, Materials Engineering Technology, or Engineering Technology.

Method

Social Network Analysis provides a macro-level analysis of the student interaction in the Google Group environment. This analysis demonstrates the nuances of the online interactions and connectivity as it considers social structure to be the patterned organization of network members and their relationships (Garton, Haythornthwaite, & Wellman, 1997). Information regarding the ties that students are maintaining show the patterns of interactions, specifically who communicates with whom, how frequently, and how information travels among the participants.

Social Network Analysis of the Google Group interactions was performed using UCINET. A visualization of the forum was conducted in order to determine whether patterns existed in participant interaction based upon topic, attribute data, gender, or major. A visualization of the forum was generated to provide a graphic illustration of the undergraduate participant patterns of communication. The visualization represented each participant as a node on the sociogram. This visualization included directional lines that demonstrate the interactions among the participants. Additionally, the social network analysis identified measures of degree, centrality, and frequency. Degree demonstrates the number of participants with whom each participant interacts. This measure is important because it describes the diversity of a student's interactions rather than just frequency. Previous research has shown a strong correlation between the diversity of a student's participation in a class's social network and the quality of their classwork (Putnik et al., 2016). Centrality shows the relative importance of each participant in a given network.

Table 1 shows all the weekly posts that the student's responded to over the term. The entire discussion board focused on developing green energy manufacturing and these questions highlight the major aspects of green energy manufacturing that the students were learning about in class. Each question also encourages the student to share their personal opinion on the topic in a way that they would not have time to do during their class lecture. The prompts provided a way to start a discussion between students taking similar courses in different parts of the country. Faculty from both universities collaborated to develop the prompts outlined in Table 1. The faculty discussed what the students at both universities were covering or had already covered at that point in the term

Table 1
Discussion Prompts

Topic	Prompt
Introductions	Introduce yourself to the other students. Please mention your major, year, and career goals. Explain what interests you in the areas of green energy and why?
Green Energy Systems	Do you see any potential implementation of green energy systems? What are the benefits of green energy systems? Please cite examples of impact you have seen as a result of green energy systems.
Wind Energy	What areas can benefit the most from green energy? What are the benefits of such systems? What are the struggles with implementing wind energy systems?
Solar Energy	How can solar energy be adapted to replace a "less green" energy system? How would this configuration benefit from the implementation of a solar energy system? Do you foresee any hurdles? Are there any possibilities for expansion beyond your initial plans?
Life Cycle Assessment	1. What is a product life cycle and what are its main phases? 2. Describe the four steps in performing life cycle assessment (LCA). 3. How do you achieve the life cycle simulation

	in goal and scope, life cycle inventory, life cycle impact assessment, and interpretation? 4. Describe the use of the life cycle approach to examine global warming potential (GWP) for the production, use, and end-of-life of your product. How is it related to greenhouse gases (GHG)? 5. Describe how Gabi 6 helps you perform the steel paper clip LCA simulation in your own computer. 6. Describe the learning outcomes from this course. The questions above are *very* pertinent to your final so please use them as practice and preparation for that!
Wrap-Up	How did the discussions of this group help you? Please be specific. What would you suggest for future green energy manufacturing discussion groups?

Participants

Students at the northeastern university were all male pre-juniors or juniors. Students at the southwestern university were a mix of males and females and all in their sophomore year. Since the northeastern university is on a quarter-system and the southwestern university is on the traditional semester system, it had to be taken into account that the groups were enrolled in universities that operate on different schedules. The northeastern university students were introduced to the group during the first week of the Fall Quarter and began participating during their second week.

Students provided a Gmail account to the online learning coordinator and then received an invitation to join the group. Upon logging in, students would see the following page depicted in Figure 1.

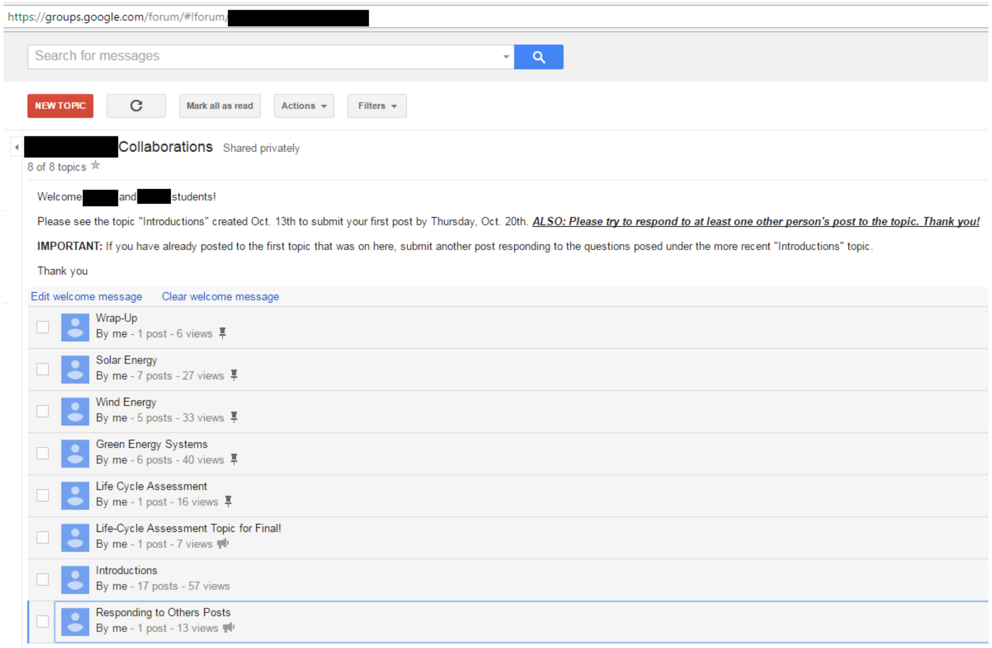

Figure 1. Google Group homepage with topics. This figure illustrates the Google Group homepage with the list of topics discussed by the students.

A new topic was added to the Google Group homepage every week. All members of the group automatically received an email when a new topic was posted or when any student responded to a topic. Although Google Group platform does not have an application for smartphones, the students can connect to their email through smartphones. The Google Group emails were delivered to the students' phones so that they could read responses and answer in real-time. It was important to clarify to the students that each prompt and post would forwarded to their email and responding directly to the email would not result in the recording of their responses to the group page. In order to have one's response recorded to the Google Group page, the response had to be written directly on the Google Group's webpage.

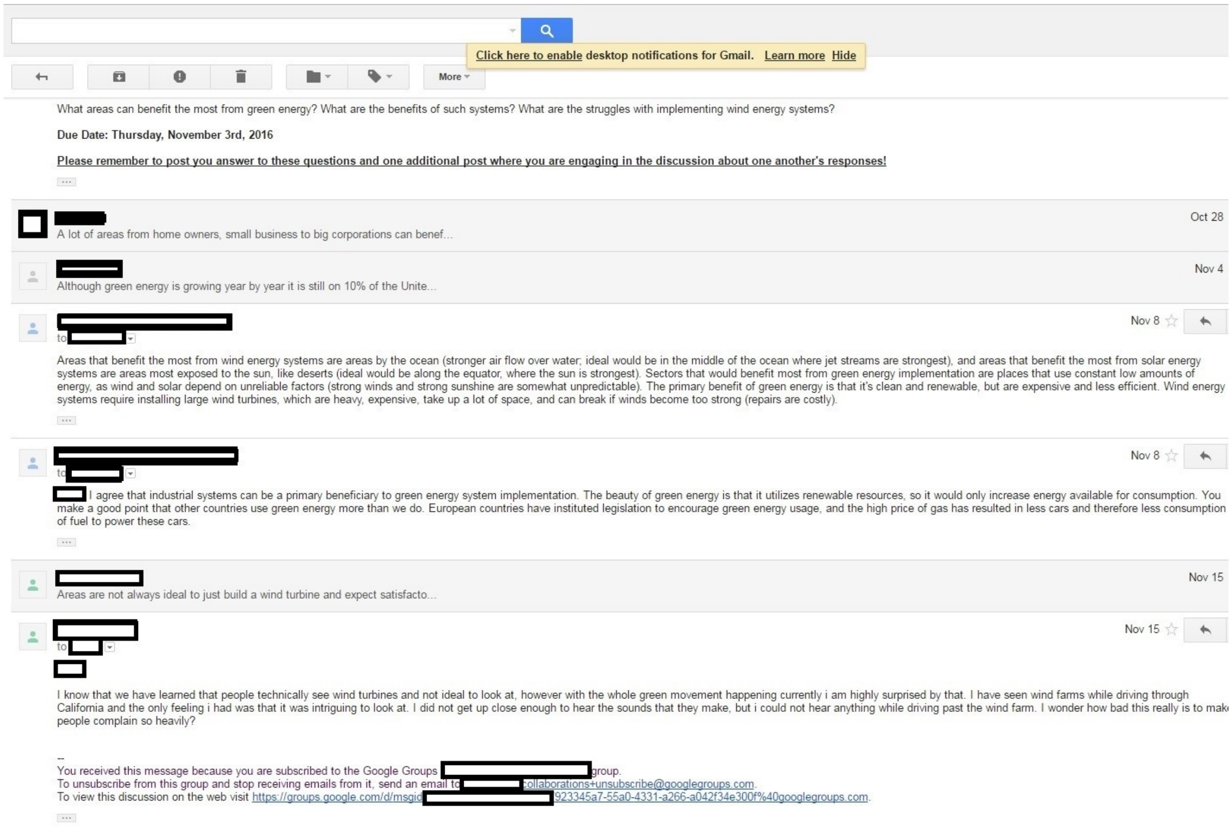

Figure 2. Student View of the Google Group. This figure provides an illustration of a student view of an email thread from the Google Group under study.

The use of start dates, due dates, and posting parameters, i.e. minimal number of posts and receiving emails provided each member of the group with up-to-date on the group activity, can be categorized as triggering methods for encouraging communication.[3] This is the initial phase where a student is prompted and reminded to respond to the prompt as a general topic. Encouraging the students to participate in other people's posts was an integration method for communication.[3]

Grading

At the end of the term, student discussion board participation was graded using a rubric, which was developed by Denise Lowe, Ph.D., the Instructional Designer at UCF's Center for Distributed Learning and is depicted in Figure 3. This rubric was selected for this research after all the students had participated in order to assess the quality of their posts. It was selected from the *Teaching Online Pedagogical Repository* as one of the recommended rubrics that reduces inconsistency in grading online discussion board posts (Chen, DeNoyelles, Thompson, Sugar, & Vargas, 2014). It was one of two simple rubrics recommended for grading online discussion boards and chosen because it had extensive tiers for grading, which allows for one to see subtle differences in quality.

Contributions	Description	Points Assigned
Provocative	Response goes beyond simply answering the prompt; attempts to stimulate further thought & discussion	20
Substantial	Response provides most of the content required by the prompt, but does not require further analysis of the subject	15
Superficial	Response provides obvious information without further analysis of the concept; lacks depth of knowledge or reasoning	10
Incorrect	Response does not accurately address the prompt; rambling and/or without consistency	5
None	No response provided to the prompt within the associated timeframe	0

Figure 3. Discussion Board Participation Rubric. This figure illustrates the rubric used to grade each student's participation in the discussions of the Google Group.

For each initial response a student posted to a prompt, a grade was provided using the rubric in Figure 3. This rubric provided the grading structure for each of the participant posts, allowing for transparency in the grading. Follow-up posts were also graded using this rubric. Each weekly discussion board score was the average of the initial post grade and the grade for the response post(s). The overall grade for the participation in the discussion board was the average of the total grades for all of the discussions.

Data Analysis

This findings section includes the analysis of the results of the sociogram visualization and the measurements of the interactions using the UCINET data. While the data set examined was not of a significant size to allow for generalizable conclusions, data analysis did demonstrate that UCINET was a useful program with which to visualize and analyze the communication interactions among the participants and that participants tended to interact in sparse ways.

Visualization

The interaction patterns and sociogram show that two participants from the northeastern university were the most central figures in the Google Group under study. Barab, Thomas, Dodge, Goodrich, Carteaux, & Tuzun (2002) have argued that empowerment design work involves identifying, understanding, and transforming the multiple activities, places, and social groups (socio-technical arrangements) with which individuals participate and in understanding what participation those various socio-technical arrangements mean to the individuals (Barab et al., 2002). The sociogram for this Google Group demonstrates that participation in the group was more important to some participants than others. Examination of metrics of the participant interactions also demonstrated this fact. In the sociogram in Figure 4, each participant is assigned a node with directed lines between each node which had a directed communication with another participant in the group. Shape is indicative of major; size is indicative of gender; color is indicative of university participant attends.

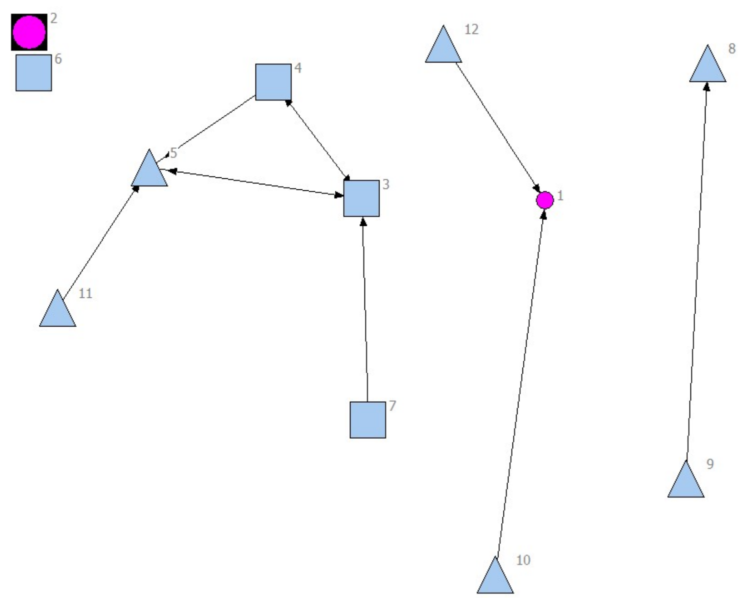

Figure 4. Sociogram of interaction among all participants in the Google Group over the Fall 2016 term. This figure provides an illustration of the sociogram which demonstrates the directed communications among the students in the Google Group.

Circle: major not known. Circle-in-box: Industrial Engineering. Square: Materials Engineering Technology. Triangle: Engineering Technology. Size is associated with gender, larger nodes are male and smaller nodes are female. Color is associated with university participant attends, pink indicates student attends the southwestern university and blue indicates student attends the northeastern university.

Measurements of interactions

Network density measures how closely knit members of a network are and is often referred to as an overall measure of interaction. Density is the proportion of existing communication relationships between members (presence or absence) divided by the total possible number of communication ties (Wasserman & Faust, 1994). Values for network density range from 0 to 100 with higher values indicating greater cohesion and frequent communication among all members in a defined network (Wasserman & Faust, 1994).

Density The network density is 7.6%. The calculation involves dividing the number of dyads in the matrix by all possible dyads, which are twelve (12). A network is completely cohesive (has a density score close to 100) organization when participants possess the capability to coordinate efficiently and effectively with all other members of the network. A network with a low density, measuring near 0, suggests participants may lack experience or familiarity with one another and coordination between participants may be limited. In previous research, high density has ben found in in smaller networks where the number of participants small (Ruane, 2012).

Network centralization refers to the concentration of communication in a network (Knoke & Yang, 2008). Network centralization values range from 0 to 100. Network density and centralization are complementary measures (Scott, 2000). Low centralization indicates greater distribution of communication across participants with no single member having a high level of communication over any other member in the network. A decentralized network could be interpreted as a highly communicative network, where information is communicated frequently between all participants. In contrast, higher values of network centralization indicate that communication is concentrated to one or a select few participants in a network, leaving some isolated or outliers. The Google Group network had a 21% network centralization value, which was somewhat low, indicating greater distribution of communication among the participants without a single central figure in the network.

In degree centrality, which is related to network centralization, is commonly used to rank individuals based on their positioning/influence in the team / network (Wasserman & Faust, 1994). Investigators have used network centralization and in-degree centrality to identify the important and influential individuals within networks (Scott, 2000; Everett & Borgatti, 2005). A person can be influential in several ways. S/he may be the person providing/initiating the communication to other members of the network (out-going communication) and a source of valuable information. A person may be influential because he/she is the recipient/target of communication from many other teammates (in-coming communication) due to his/her role in the network or due to his/her reputation as a valuable source of information. In-degree centrality (in-coming communication) is the sum of communication ties from all participants in the network standardized by dividing the sum by all possible communication relationships (Wasserman & Faust, 1994). An individual is considered prominent, important, or powerful when he/she has a high level of in-degree centrality Wasserman & Faust, 1994). The in degree centrality calculations for this network indicate there were four (4) important or influential figures in the network, all of whom are from the northeastern university.

Discussion

Engagement and interaction is critical to the successful implementation of collaborative online learning experiences (Gunawardena et al., 2006; Beetham, H., & Sharpe, R., 2013). In this particular environment, the data suggests that participants from the northeastern university were more engaged than the students from the southwestern university. The sociogram demonstrates that participants tended to engage directly with other participants of the same major. This may be due to the structure of the discussion questions. Further research may be useful to identify the ways in which, over more extended period of times, different groups of students respond to different types of discussion prompts.

In spite of extra-credit incentives at southwestern university and continuous encouragement from professors at the northeastern university, receiving participation from even half of the students in the Google Group was a struggle. The first topic, Introductions, was the most successful discussion with 50% of all the participants answering the general topic question. Of that 50%, 67% answered the general topic question and also responded to another post. Participation in the discussions of prompts 2 - 5 averaged 20% participation from all of the students. Of that 20%, an average of 67% of the participants responded to another participant's post in addition to answering the general topic question. For the final topic discussion, Wrap-Up, there was no participation. Overall, the students, who participated, were consistently active throughout the term. This study has implications for future research to determine the student perspective regarding this Google group and the impacts for them in their studies.

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