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Examining relationships between student interactions with peers and resources and performance in a large engineering course using Social Network Analysis

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Background

The purpose of this research was to identify and compare student peer interactions and use of course resources to student academic performance within the context of a large, face-to-face (f2f) engineering course. Today more than ever before, engineering instructors are able to provide students access to a variety of course specific resources, ranging from traditional, printed text-based information, to web-based activities which support students' individual processes of learning [1]. Moreover, in keeping with the theoretical foundations of social learning [2, 3], engineering instructors may often encourage students to "work in groups" to prepare assignments and learn technical course content through group-based problem solving. Along with the cognitive and emotional benefits of social learning, group work is considered an important strategy for promoting the development of the teaming and communication skills needed for professional engineering practice [4]. Based on these contemporary instructional practices in engineering, new understandings of a) how engineering students interact with peers and use course-specific resources and b) how peer interactions and resource use correlate with course performance are essential for supporting engineering instructor decisions as they select and design course resources, develop group work activities, and implement new interaction strategies in engineering courses.

To investigate potential relationships, we employed Social Network Analysis (SNA) and Qualitative Content Analysis (QCA) to analyze and compare student survey responses about peer interaction and resource use to student performance data within the context of a 2^{nd} year engineering materials science course taught during the spring 2019 semester. Researchers have applied SNA across social science disciplines to quantitatively describe the interactions between individuals in a network. For example, SNA has been used in engineering education to analyze faculty communities of practice [5] and to compare instructor and teaching assistant (TA) online forum participation [6]. While use of SNA to better understand how student interactions with peers may affect course performance exists in the computer-supported education [7] and online learning [8] literatures, limited research examines similar interactions in the f2f engineering course context. Generally, SNA has been applied to analyze online interactions more frequently than f2f interactions. One potential reason for this disparity is the relative ease of collecting interaction data through learning management systems in computer-supported learning environments compared to identifying interactions in f2f courses.

Literature Review

As described in this review, current literature regarding students' resource usage and performance has established that traditional course resource use and group collaboration can relate to performance, but findings are sensitive to research context. This existing body of literature is limited, however, in that it does not detail the effects of combining peer interactions and traditional resources in f2f contexts. Moreover, the limited research addressing these issues does not also examine student motivations for resource selections.

Course Resources

Prior research has compared the amount of time students spend on different course resources (i.e., class attendance, textbooks, online resources, etc.) to student performance in, f2f engineering courses for the purpose of identifying which resources are most effective in teaching course material [1, 9]. Ellis, Han and Pardo [10] found that the depth of interactions with online and more traditional resources also correlated positively to student performance. Furthermore, researchers have identified time-based efficiency as a motivation for resource selection in engineering course contexts [1, 11]. In sum, prior work suggests that it is beneficial for engineering instructors to understand a) how interactions with course resources, including peers and supported and unsupported materials, influence student performance and b) whether students' selection of resources aligns with instructor goals.

Group Influences on Performance

Individual researchers have observed improvement in student performance through systematic grouping of engineering students; grouping students by personality type was shown to result in the greatest performance improvements [12]. In their literature review, Kalaian, Kasim, & Nims' [13] found that improvements in engineering student performance due to teaming was consistent across multiple studies. Researchers have applied SNA to form idealized Belbin Role-types based student teams [14] and to evaluate team performance [15] in traditional f2f engineering courses. Taken together, these studies provide evidence that, when implemented effectively, group work can improve student performance in engineering while achieving goals for teaming and collaboration set by program requirements.

Importance of Context

Dawson [16] reported that higher performers in a f2f engineering course were more likely to have asynchronous online interactions with instructors and other higher performers than with moderate or lower performing students. Others have found that asynchronous online learning environments encouraged mixed (i.e. higher and lower) performer collaboration [17]. Casquero et al. [17] suggested that course environments mediate these relationships between student interactions and performance. Although researchers [18] have found that student online interactions correlate positively to student course performance in a small (40 students,) f2f, project-based, engineering course, a need exists to understand the potentially unique relationships that exist between student interactions and student performance in the context of large, f2f engineering courses.

Interaction Types and Frequency

Among small groups of engineering students, Zhu and Zhang [19] found that network density was positively correlated to team performance. Zhu and Zhang's results further indicated that students are more likely to perform well when their group interactions are shared evenly among group members. Others have shown that specific types of interactions may be preferred by certain types of students. For example, Grohs, Knight, Young and Soledad [9] found that the highest performers in a large engineering course spent the most time solving problems independently. Ellis, Han, & Pardo [10] reported that students who understood the material best and chose to collaborate, did so with fewer collaborators and for less time than those who did not present understanding of the material. These results suggest that effective collaboration in a f2f courses may be promoted by the presences of smaller, more dense peer groups.

Research Questions

To add to the existing literature, this study examined the relationships between student interactions with peers and course resources and student exam performance in a 2^{nd} year f2f engineering course. In addition, this study explored student interaction preferences and identified student motivations for changing these preferences during the course. This paper expands on preliminary results [20] to answer the following research questions (RQ): (1) What factors influence the formation and evolution of student networks in the course (QUAL/QUAN)? (2) To what extent do SNA measures correlate to individual student performance (QUAN)? Specifically, this paper reports on a) student interaction patterns (i.e. networks) during the semester, b) relationships between student interaction patterns and course performance as measured by exam grades, and c) student motivations for changing their interaction preferences during the semester.

Methods

Course Context

This study was conducted during the spring 2019 offering of a 2^{nd} year engineering materials science course. The course is required for all students enrolled in the mechanical engineering program at our institution. The course comprises two weekly, 75-minute, f2f lecture sessions. An associated materials science laboratory course is typically taken concurrently, which comprises one two-hour lab session every other week. Lectures follow a traditional format focusing on general concepts to be applied later by students on homework problems assigned weekly. Laboratory sessions provide students with opportunities to work in groups of two to four students to observe and conduct material property testing, including hardness testing, tensile testing, and critical crack length estimation, in a laboratory environment. At the conclusion of each laboratory session, student groups are required to synthesize their findings, including material property estimations, in an individually written laboratory report.

Participant Selection

Participant recruitment was conducted in person by the researchers during the first day of class. Informed consent was collected at the start of the first survey in accordance with an approved institutional review board (IRB) protocol. To incentivize student participation, the course instructor provided one point of extra credit on the final exam for each survey taken.

Data Generation

Resource frequency and perception data for this study was generated through use of three online surveys that were administered in Qualtrics periodically throughout the semester. Exam scores were used to identify student performance.

Survey 1. The first survey (i.e., Survey 1) was implemented once during the second week of the semester. The purpose of Survey 1 was to query participants about their anticipated interactions with peers and resources and their motivations for participating in groupwork in the course. Survey 1 identified participants anticipated peer interaction by asking the following question, *"Please list (by first and last name if possible,) any classmates currently taking [course name] who you think you will study materials science with this semester."* To identify participants' motivations for choosing/not choosing to interact with peers, Survey 1 asked participants, *"Please state the reasons why you do/don't anticipate studying with classmates taking [course name]."* Participants were provided a text box to describe the reasons behind their intentions to/not to interact with peers in the course.

Survey 1 identified participants' anticipated use of available course resources by asking following question, "*How often do you anticipate using [course resource description] for [course name]?"* Participants were provided the following list of course resources to respond to:

- Course material (textbook, lecture notes, videos of lectures on LMS)
- Online forums (LMS provided open forum)
- Publicly available Internet resources (Google, Chegg, Coursehero, Slader, etc.)
- People designated to provide support (instructors, TAs, engineering tutor center)
- Interactions with prior students (i.e., people not currently taking but who have already taken the course, such as classmates in other courses and friends)
- Interactions with classmates currently taking the course
- Class sessions

Students were asked to describe their resource use by selecting one of the following discrete, weighted responses: More than once per day (6), every day (5), every other day (4), every 3-4 days (3), once per week (2), less than once per week (1), and never (0).

Survey 2. The second survey (i.e., Survey 2) was administered every two to three weeks, starting on third week of the course, for a total of four iterations. Survey 2 asked participants to identify their use of each course resource by asking following question, *"How often did you use content resources provided by the course for help in [course name]?"* followed by a resource description. Resource use responses were weighted the same as Survey 1.

Survey 3. The third survey (i.e., Survey 3) was administered every three weeks, starting on the fourth week of the course, for a total of four iterations. Survey 3 identified participants' network of peer interactions by asking the following question: *"Please list the classmates currently taking [course name] who you studied materials science with during the past three weeks?"* Survey 3 also asked participants to rate the perceived effectiveness of each individual course resource by stating: "*Please rate the following resources according to their effectiveness in helping you learn the [course name] material during the past three weeks,"* followed by a resource description. A seven-point Likert scale was provided for the participants to rate each resource from "very effective" (6), to "not at all effective" (0). In addition, participant demographic information was collected with the final iteration of Survey 3.

To identify motivations for and barriers to changes in resource use, Survey 3 also asked participants, "*Have you changed the amount of times you used any of the following course resources during the past three weeks? For the course resources that have changed, state the reason for the change*." Participants were provided a text box to type a written description of their reason(s) for changing resource(s) use.

Exam Scores. Participant performance was measured using exam scores provided by the instructor at the end of the course. Two midterm exams and one final exam were administered in class by the primary instructor during the 15-week semester (Figure 1).

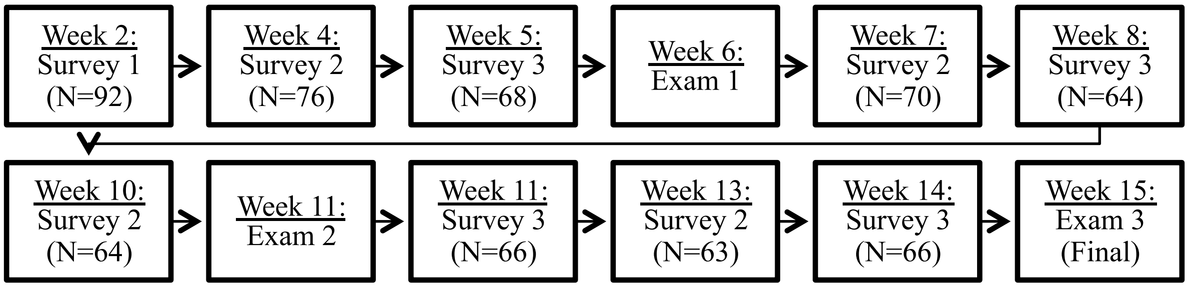

Figure 1. Survey and exam implementation during the course.

Attendance Scores. The instructor randomly assigned eight in-class quizzes eight times throughout the semester and provided credit for completion. These scores were averaged across the semester and each student was assigned an attendance grade which made up nine percent of their final grade in the course.

Data Analysis

SNA is an analytical technique used to describe interactions between *actors* (i.e., nodes) in a network through weighted, directional connections called *edges*. This study considered both students in the course and course resources as actors. The connections between peers were directed (from the student reporting to the students reported about,) and non-weighted. Connections between resources were symmetric (non-directional) and weighted by the frequency of their interactions.

To conduct SNA, adjacency matrices were developed that described interactions from row actor to column actor through the assigned edge weight. To analyze the adjacency matrices, we developed network plots to provide graphical/qualitative network representation and then calculated quantitative descriptions of network and node relationships called SNA measures. Degree Centrality (DC) is an SNA measure that identifies the number of network ties leaving and entering a node. We found DC to identify the combined number of peers a participant interacted with and the number of peers who reported interacting with them.

To compare participant interactions to their course performance, we employed least-squares linear regression of participants' DC and resource use to the exam scores. To identify participants' reasons for changing resource use, we manually coded responses to the open-ended Survey 3 questions using QCA and in vivo codes [21]. Coded responses were then inductively grouped to understand the reasons why students chose to change their resource use during the semester and to assist in interpreting peer network and resource use results.

LIMITATIONS

This study is limited in at least two ways, including participant recruitment and participant mortality, and the accuracy and completeness of participants' retrospective responses. Because SNA is sensitive to missing network nodes [22], quantitative comparisons are limited by lack of information from those students who chose not to participate in the study or who dropped out during the study. Second, the accuracy of participants' responses was limited by participants' ability to recall detailed information about their interaction and resource usage after the fact. In addition, although survey questions asked participants to identify time spent interacting with each peer in their network, few students gave such detailed descriptions. Lack of detailed responses limited development of the peer interaction networks. For those participants who chose to provide only their names on surveys (presumably for the purposes of receiving extra credit), their responses were removed from data.

FINDINGS AND DISCUSSION

Sixty-six of 118 (56%) students enrolled in the course participated in all surveys. Participant demographics are shown in Table 1. Participant demographics reflect the larger student population in the course and the college of engineering at this university.

Table 1. *Participant demographic information (N=66)*

Descriptor	Category	Number of Participants (%)
Age (years)	18-21	25 (38)
	22-25	31 (47)
	> 25	10 (5)
Employment (hours/week)	≥ 40	10 (5)
	< 40 and ≥ 20	12 (18)
	< 20 and ≥ 0	24 (36)
	none	27 (41)
Gender	Male	51 (77)
	Female	15 (23)
Residence	Off campus school housing	27 (41)
	On campus school housing	13 (20)
	Off campus private residence	39 (26)
Race	White	62 (94)
	Asian	2 (4)
Marital Status	Married, or in a domestic partnership	19 (29)
	Single (never married)	47 (71)
Citizenship	U.S.	63 (95)
	Foreign national	3 (5)
Hispanic, Latino, or Spanish origin	No	64 (97)
	Yes	2 (3)

Note. Totals do not equal 100% due to rounding error and participants who chose not to disclose all requested information.

To gage the validity of participant responses regarding resource use, the random attendance quiz scores were compared to participants' reported class attendance scores. The average attendance score across participants was 94%, while the average perceived attendance on the scale from 6 (attended every class) to zero (never attending class) was 5.87. These results provide evidence that the participants' responses are similar to their actual interactions. High course attendance may have been motivated by the attendance quizzes that comprised nine percent of students' final grade.

Peer Interaction Network Trends

The evolution of peer interactions within the course is shown in a time series of network plots computed on even three-week intervals (Figure 2). Network plots were developed using Gephi open source software [23].

Network plots of peer interaction show a trend in interactions that began with a large, loosely connected peer group at the beginning of the course. This large loosely connected group evolved into several, small group networks by the end of the course. While the maximum number of survey responses was 92 and the course enrollment was 118 students, participants identified a study network of 128 individuals. This finding suggests participants had study partners outside of the course. In addition, evolving subgroups became denser. This increase in sub-group density suggests students became more closely tied with their select group of study peers and less tied with those outside of their subgroup.

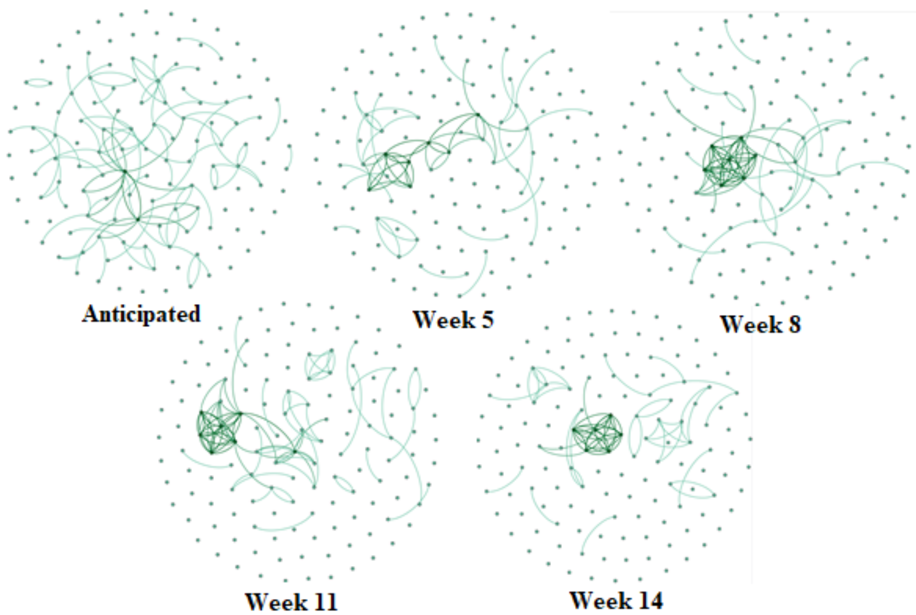

Figure 2. Time series network plots depicting the evolution of peer interaction networks during the course. Dots represent students who participated in the survey or were identified by another participant as someone they interacted with during the course. Arcs represent reported connections between students. Connections are directed in the clockwise direction.

The results of the linear regression analysis conducted between participant degree centrality (DC) values (i.e., the total number of people with whom each participant interacted) and exam scores is provided in Table 2. Participants' DC values were calculated using a freely available SNA software program SocnetV [24]. Linear regression analysis was performed using Excel.

Table 2. *Linear regression coefficients and p-values for comparing each participants' degree centrality (DC) value to their exam scores*

	Week 5	Week 8	Week 11	Week 14
Regression coefficient (b)	-0.16	0.04	0.50	0.73
p-value	0.80	0.94	0.32	0.21

While the regression coefficients are not statistically significant, we note that the relationship between DC and exam performance shows an increasing positive effect of student interactions on exam performance over the course of the semester (i.e., increasing positive regression coefficient). Considering the qualitative (Figure 1) and quantitative (Table 2) results together, we suggest that participants may have identified and increased peer ties, which promoted their learning and removed other, less effective ties throughout the course The finding that smaller, dense study networks may have positive effects on engineering student performance is similar to trends observed in other studies [10, 19].

Peer interaction and Course Resource Usage Comparison to Performance

To compare participant's perceived effectiveness and reported resource use to course performance, we calculated the least squares linear regression coefficient comparing resource use for each resource to exam scores as shown in Table 3.

Table 3. *Linear regression coefficients and p-values for participants' resource use compared to exam scores during the course.*

		Course content material	Online forums	Publicly available internet resources	People designated to provide support	Interactions with prior students	Interactions with classmates currently taking the course	Class sessions
Anticipated	Coeff.	-0.29	-2.00	-2.54	-3.73	-1.62	-0.82	n/a
	p-value	0.86	0.03*	0.02*	0.00*	0.08	0.37	n/a
Week 4	Coeff.	-0.89	-2.05	-3.27	-1.65	-1.71	-0.55	n/a
	p-value	0.52	0.08	0.00*	0.12	0.18	0.59	n/a
Week 7	Coeff.	0.25	0.29	0.89	-2.36	1.30	1.06	-2.06
	p-value	0.89	0.84	0.54	0.17	0.47	0.41	0.55
Week 10	Coeff.	2.26	-0.89	-1.73	-1.02	-1.57	-0.23	4.49
	p-value	0.23	0.63	0.26	0.58	0.53	0.88	0.14
Week 13	Coeff.	1.74	-0.60	1.36	-1.51	-1.54	0.14	1.65
	p-value	0.40	0.69	0.37	0.40	0.38	0.91	0.38

Note. The class column has no values for the first two surveys as class sessions were inadvertently left off the anticipated survey, and all participants indicated they attended every class session for week 4.
*p < .05, two tailed

As shown in Table 3, participants who reported higher use of publicly available internet resources (e.g. Chegg, Coursehero, Slader, etc.) during week 4 performed worse on the following exam with statistical significance. While results for all resources after week 4 are not significant, the change from statistically significant negative regressions and to non-significant, positive and negative regressions suggests that participants identified ineffective study methods and adapted their study resource use accordingly as the course went on. These results may reflect that, early in a second-year engineering science course, participants are still identifying which course resources are effective for their learning. While these participants identified resources that were ineffective for them, which resources are most effective has yet to be discovered. Interestingly, at the anticipated time, course content material and interactions with classmates were the only resources without a negative and at least marginally significant regression. This trend may be reflective of Grohs, Knight, Young and Soledad's [9] findings which showed those students who performed well from the course start spent most of their time solving problems independently, with fewer interactions across other resources.

To analyze the course-level use of each resource, we summed the weighted reported use of each individual course resource. Resource use was weighted by reported usage frequency from 0 (i.e., never used) to 6 (i.e., used multiple times per day). Then, total weighted resource use was normalized by the number of participants to compare use across all resources. Normalized course-level resource use is shown in Figure 3.

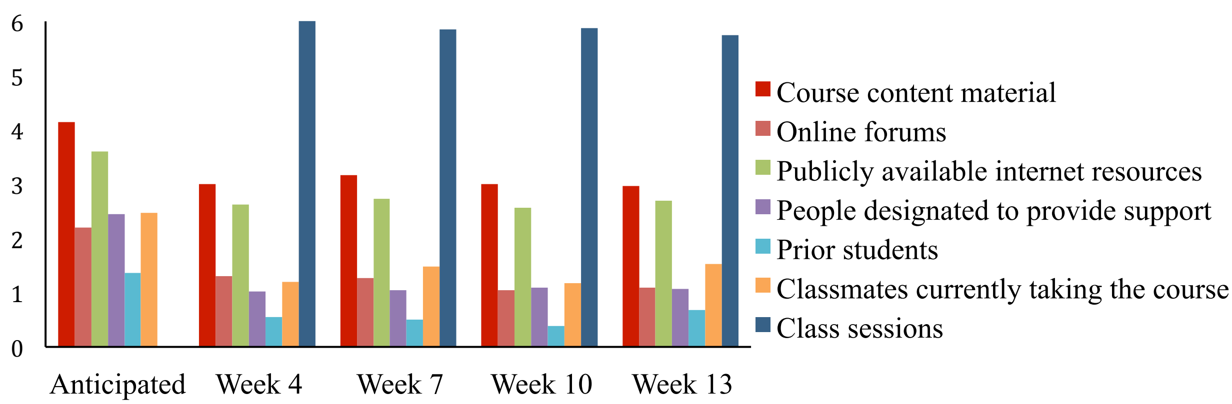

Figure 3. Average course-level use of resources during the course
Note. Class sessions were inadvertently left off Survey 1 (i.e., anticipated use).

Figure 3 shows participants' use of each course resource decreased from anticipated use at week 2. (We note that high levels of anticipated resource use may be reflective of participants' over-eagerness during the first week of the course.) After an initial decrease across all resources at Week 4, resource use for all resources remained relatively constant throughout the remaining course. Consistently over time, the most frequently used resources were class sessions, course content materials provided by the instructor, and publicly available internet resources (e.g. Chegg, Course Hero, and Slader) in that order.

To analyze the participants' perceived effectiveness of each resource, we summed the reported effectiveness vales for each course resource across all participants. Effectiveness was weighted from 0 (i.e., not at all effective) to 6 (i.e., very effective). Total course resource effectiveness values were then normalized by the number of participants in order to compare effectiveness across all resources. Course resource effectiveness is shown in Figure 4.

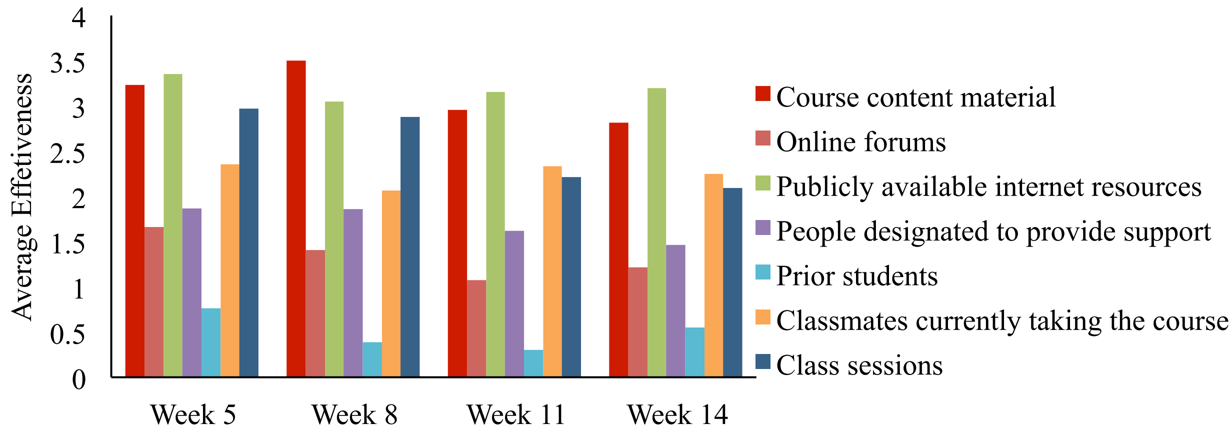

Figure 4. Average course resource effectiveness as perceived by participants during the course.

While use of each resource remained consistent throughout the semester after Week 1 (Figure 3), participants' perceived effectiveness of class sessions lessened over time (Figure 4). Course content and publicly available internet resources were the highest valued and most frequently used resources (not including class session attendance). While this course was offered in a traditional setting, participants indicated the second most used resource was publicly available online resources such as Chegg, and this resource type was most highly valued for three of the four surveys. When comparing the effectiveness of each resource, we note that resource use closely aligns with resource effectiveness (Figures 3 and 4). The caveat to this trend, however, is that participants reported attending class despite reporting decreasing perceptions of the value of course attendance.

Key Reasons for Resource Use Change

General reasons for resource use change. The QCA of open-ended survey responses yielded several code groups that described participants' motivations for changing their resource use during the course. Three of these reasons for changing resource were found to be consistently reported for all resources: a) students needed an increasing amount of help completing homework assignments. For example, one student said, "The past couple of homeworks were more difficult, so I had more questions and thus used the discussion forum more;" b) Participants were preparing for a test. This reason was expressed as: "Our Exam was the last week, so I reread chapters to prepare for the test;" and c) Participants wanted to better understand the course material. This reason was expressed as: "(I) watched YouTube videos on certain topics covered in class to better understand the material." A summary of code counts is shown in Table 4.

Table 4. *Resource use change and general reasons participants gave for changing course resource use*

	Course content material	Online forums	Publicly available internet resources	People designated to provide support	Interactions with classmates currently taking the course	Class sessions
	Response Count (%)					
Increased use	70 (96)	22 (95)	22 (52)	21 (91)	33 (94)	12 (75)
Decreased use	3 (4)	1 (5)	7 (17)	2 (9)	2 (6)	4 (25)
Homework help	15 (21)	6 (27)	15 (36)	3 (13)	7 (20)	0 (0)
Studying for a test	24 (33)	0 (0)	7 (17)	9 (39)	11 (31)	0 (0)
General concepts	15 (21)	0 (0)	11 (26)	0 (0)	5 (14)	9 (56)

As Table 4 shows, most participants indicated increases in resource use when asked why they had changed how often they used each resource (Table 4). However, reported resource use of all resources appears to have declined when viewing participants reported resource use (Figure 3). This finding may indicate: 1) participants perceive an increase in resource use when explicitly asked about how their habits have changed despite actual resource use decrease, 2) participants' ability to recall resource use is inaccurate, or 3) participants recognize increases in their resource use, and do not recognize decreases. The latter would explain why overall resource use went down (Figure 3), despite participants identifying mostly use increases in their open-ended survey responses (Table 4).

Resource-specific reasons for resource use change. In addition to describing more generalized reasons for changing course resources use, participants described specific reasons for adopting certain course resources during the semester. Participants (16% of the 73 responses) described moving toward use of course content material due to increasing perceptions that the resources they were using were not effective for them. For example, one participant stated: "My other study habits didn't seem to be helping me so I tried to resort to studying the lecture material and book. I've been doing a lot of this recently." Others expressed dissatisfaction with lectures and described reading the textbook instead. Four participants explicitly indicated a decrease in class attendance as the reason they began using content material more.

Participants (18% of the 22 responses) reported moving toward use of online forums because they had just become aware of this resource. One participant wrote, "I found out that there is a discussion forum for each homework where you can ask for help on assignments." This finding suggests that instructors should reiterate resource availability throughout the semester, as some students continue to determine which resources are either effective or ineffective for them throughout the course.

Participants (23% of the 35 responses) moved toward interactions with classmates, which we labeled as improving social connections. As one participant wrote, "I found some classmates willing to talk to me" and supports the social difficulty barrier identified in preliminary results [20]. Furthermore, responses suggest that students were able to overcome what they had identified as a barrier to studying with peers early on during the semester.

It is important to note that participants were given the opportunity to provide their reasons for changing course resource use only if they indicated changing their use of a particular resource in the survey. As a result, these findings reflect reasons why participants changed, rather than initially chose, a given resource.

CONCLUSIONS

Results of this study indicate several key findings. First, engineering instructors may benefit their students' efforts to learn course material by actively providing group work supports throughout a 2nd year course. Our results show that participants slowly identified group members and effective group study methods throughout the semester. Although a substantial, loosely connected network existed at the beginning of the course, more dense subgroups evolved as participants reinforced effective connections while removing ineffective ties. These findings, taken together with other findings that report on the effectiveness of forced groups [12, 13] and our own preliminary results which indicate social difficulty as a key barrier to forming groups in engineering [20], suggest that engineering instructors should be proactive in support of group work early on in a course or program. By guiding students into small group work early in a course, instructors may jumpstart engineering learning through the process of identifying effective peer interactions earlier than will naturally occur. In addition, guided group work in 2nd year courses has potential to prepare engineering students for future work in engineering teams later in their engineering education as well as in the engineering workplace.

A similar trend was noted in qualitative findings of the open-ended survey responses. As the semester progressed, participants changed their resource use as they identified which course resources were not helping them learn the material. Considering the context of this study, this finding suggests that 2nd year engineering students may be still identifying personally effective study approaches and methods. For example, we found that participants changed their resource use during the semester due to experiences in the course such as difficulty with homework problem solving, poor exam performance, and a lack of general concept understanding. Moreover, participants shifted to increased use of course content material as they found that the other resources they selected initially were not as effective for their learning. Thus, instructors may benefit student learning in 2nd year engineering courses by providing more guidance on study approaches, as well as emphasizing which resources are essential to learning course objectives.

The final key finding of this study is the importance of publicly available online resources, not supported by the course or instructor, to the participants. Participants identified online resources, such as Chegg and Coursehero, as the most effective resources for them across three of four surveys administered during the course. This finding further supports those of earlier studies set in 2nd year, f2f engineering courses [11]. As these online resources are available to all engineering students, whether or not their instructors endorse their use, instructors should consider the implications of the value and time students give to public online resources when designing course curriculum in traditional f2f engineering courses.

IMPLICATIONS FOR FUTURE RESEARCH

Our future research will identify overlap between individual resource use to explore which resource combinations are used by both higher and lower performing students. Other research has identified that blends of resources most accurately defines engineering student study habits [1, 11]. Cluster analysis has shown promise to improve the identification and analysis of similar combinations [9, 10]. While the participation rate in this study (66/118 or 56%), could be considered moderately high for survey research, non- or incomplete participation among students in the course and participant mortality negatively affected our ability to track interactions and network evolution during the course. Future work will include expanding the study beyond a single course to better enable us to explore changes in network effectiveness over time. To capture more interactions, including those that go beyond the boundaries of the course, future work will examine network development on a cohort basis, beyond a single course and semester, to increase confidence in the trends identified in this study. As well, network analysis should be conducted in a similar context with forced groups to better understand the effectiveness of the forced groups on student performance and the resulting changes in other course resources' use. Finally, while this study supports the finding that some engineering students perform well by engaging alone with course resources [9, 10], potential exists for these students to have a high positive impact on their engineering peers. Future research should include network analysis of the group placement and resulting impact of these students.

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