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Using Social Network Analysis to Evaluate the Functioning of a Class With Multiple Collaborating Groups

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Abstract: This study uses Social Network Analysis (SNA) to evaluate the Communities of Practice (CoPs) formed around a multidisciplinary graduate course in which students work in small teams to complete a class project. Each team has an assigned subtask for the larger project. Students must collaborate within teams to produce their designated component and coordinate across teams to integrate the larger project. Coordination and communication within and across teams were done through the Slack platform. We analyzed messages sent on Slack via SNA, allowing us to evaluate the class participation, communication, and interaction. In this analysis, we identified the three types of group-group interactions described by CoP theory: overlaps, boundary practices, and peripheral connections. We also used the message dates to analyze how group-group interactions and communication changed throughout the course. Researchers can use this methodology to analyze and evaluate courses with multiple collaborating groups and instructors to monitor and improve their classes.

Introduction

In order to pursue a successful STEM career, it is necessary to develop not just technical skills but organizational skills such as collaboration and communication (World Economic Forum, 2017). However, gaps persist between industry expectations and students' skills upon graduation, leading recent graduates to experience frustration, nervousness, and anxiety when entering the professional world (Kolmos & Holgaard, 2019).

In response to this need, we analyzed an existing STEM course: Design of a Robotic Computer Vision System for Autonomous Navigation (RCAN). In contrast to many courses, this one is designed to emulate a professional environment. Students in this course work in teams to develop subcomponents of a larger robotic platform. The students must collaborate within their team on their assigned task and coordinate across teams to integrate the larger project. Social network analysis (SNA) offers a suitable methodology to evaluate intra- and inter-group collaboration and it has been applied successfully to assess interaction and participation within CoP or highly collaborative environments (e.g., Williams et al., 2013; Ma et al., 2019)l; among educational researchers (e.g., Queupli & Muñez-García, 2018); and in teaching-focused communities (Ma et al., 2019), among others. In the present context, the students communicated using the Slack platform which offers a natural medium for our analysis. Our work is grounded in the CoP theory and uses SNA methodology for our analysis.

Background

Theoretical framework: CoP theory

Wenger developed the idea of a community of practice as a group of people who share purposes and methods, which emerge from the needs of a context, with the negotiation of shared meaning and forms of participation, including tools, symbols, concepts, procedures, criteria, etc. (Lave & Wenger, 1991; Wenger, 1998). The CoP framework has been successfully applied in different settings including cross-institution communities (e.g., Kirkman et al., 2013) and informal educational contexts (e.g., Kim et al., 2020). However, few studies have used this theoretical framework to develop or research experiences in a classroom context in part because there are limited strategies for evaluating the practical impact or group structure (McKellar et al., 2011; Díaz et al., 2022a), and existing methods rely on qualitative methods and are extremely time-consuming.

Social Network Analysis (SNA)

Social network analysis is a quantitative analytical technique commonly used in education to analyze and visualize communication networks or group environments (Cela et al., 2015). SNA allows us to capture the interaction, communication, and support that occurs within and across teams by representing the communication structures as graphs where individuals or groups are represented as nodes and the edges between them represent communicative acts, exchanges, or other implicit or explicit social relations. A literature review of SNA in higher education noted that: "We need to study and test the roles of committees and other meaningful subgroups" (Kezar, 2014, p.112).

Answering that call, our research examines the following research questions using the data from the RCAN course:

1. How did students communicate within and across groups?
2. How did the class communication patterns change during the semester?

Methods

Context and setting

The course was taught in the Spring 2017 semester at a large public research university in the Southeastern USA. Twenty-six students were assigned to seven teams by the instructor based on their preferencesEach team was charged with developing one subcomponent of the robot. The SLAM teams were devoted to machine vision, and included the two monocular vision teams SLAM-A and SLAM-B and the stereo vision team SLAM-S. CTX teams focused on context awareness to facilitate navigation. The HARDW team was responsible for the robotic parts, sensor control, and computer integration, and the CONTROL team was responsible for the path planning and navigation of the robot.

Data sources

Students in the course were required to communicate primarily through Slack. At the beginning of the course, the instructor created eleven default channels: seven single-team channels; one channel for the entire class (GENERAL); one for team leaders (TEAMLEADER); one to facilitate the communication among the SLAM teams (SLAM-OVERVIEW), and one between the CTX teams (CONTEXT AWARENESS). Direct messages were discouraged by the instructor and students were guided to use the public channels as much as possible.

Data analysis

We downloaded all of the public messages as transcripts in JavaScript Object Notation (JSON) format using object literals of JavaScript. The downloaded messages record all of the information within a server, including when they were sent, who sent them, what channel they were sent to, and whether the messages were the start of a conversation or a reply. Using a combination of Neo4j (https://neo4j.com/product/bloom/), Cypher (openCypher, 2017), and Python we can create complex queries for the database and extract knowledge about how team members communicated. We generated descriptive statistics for the messages sent by each student within their group and to other groups. We generated graphs showing the social network using Gephi (https://gephi.org/).

Results and discussion

How did students communicate within and across groups? (RQ1)

Students sent a total of 5,969 messages. 72% of the messages (4,269) were exchanged within team channels, and 28% across teams. This suggests that tasks involving internal teamwork - setting up the team's designated subcomponent - required more frequent discussion and likely more effort than cross-team coordination tasks.

The teams that had the most frequent internal communication were SLAM-B (1,350 messages) and SLAM-S (914 messages). By contrast, the HARDW team had the fewest messages both within and outside their team; this finding aligned well with observations by the instructor and interviews with class participants (reported elsewhere) that the team was isolated and not very responsive to other groups.

To shed light on cross-team interaction, we generated network graphs with each team channel as a node and cross-team messages as directed arcs with direction indicating the sender and recipient of the messages (Fig. 1b). To facilitate interpretation we only show connections with five or more messages. The thickness of the arcs is proportional to the number of messages sent. Purple outlines show areas of greatest interaction across teams.

The strongest connections were between teams with similar tasks and who used similar instruments: the CTX cluster at the top and the SLAM cluster at the bottom left. The CTX cluster includes the single-team channels CTX-A and CTX-B and the ContextAwareness channel. The SLAM cluster includes SLAM-A, SLAM-B, SLAM-S, and the instructor-created channel for communications coordinating these three groups, SLAM-OVERVIEW.

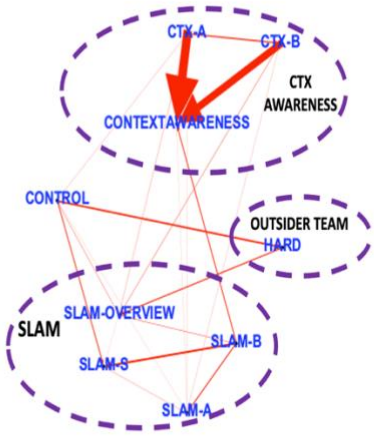
Consistent with CoP, we identified the connections within the CTX cluster and within the SLAM cluster as "overlap" connections, which are generated when teams share similar objects, challenges, and procedures within their communities. The SLAM teams, for example, are jointly in charge of designing and implementing the robot's vision system. They have common goals and tools but also some differences, e.g., lasers vs. cameras for object detection. When designing a course with intra- and inter-group cooperation, having similar learning objectives and common tools across teams will ease coordination.

Figure 1
(a) Distribution of Messages Sent by Teams During the First and Second Part of the Class and (b) SNA of Connections Across Teams, Showing Areas of Greatest Interaction

	Part 1				Part 2			
TEAM	Within	Across	Ratio*	Total	Within	Across	Ratio*	Total
CONTROL	302	80	3.78	382	171	201	0.85	372
SLAM-A	103	34	3.03	137	69	152	0.45	221
CTX-A	158	133	1.19	291	219	218	1	437
SLAM-B	502	111	4.52	613	848	172	4.93	1,020
HARD	317	45	7.04	362	178	80	2.23	258
CTX-B	120	94	1.28	214	368	151	2.44	519
SLAM-S	420	95	4.42	515	494	134	3.69	628
TOTAL	1,922	592	3.25	2,514	2,347	1,108	2.12	3,455

*Ratio was calculated as Within/Across messages.

(a)



(b)

The arcs *across* the SLAM and CTX clusters reflects "boundary practice" connections. This type of connection is established between communities engaged in different but connected activities. The CONTROL team has a peripheral connection with the CTX and SLAM teams. Connections of this type develop when the CoPs increase the permeability of their groups to allow a selective exchange of information. From the teacher's perspective, these results were expected and aligned with the tasks developed in the CONTROL team.

Finally, our network diagram shows that the HARDW team was an "outsider", with comparatively low participation and communication. The class was not designed to have an outsider group, so this represents a challenge for the project and instruction. Recognizing outsider teams with a practical methodology like SNA on Slack data will allow teachers to design timely interventions fostering greater participation by students and teams.

How did the class communication patterns change during the semester? (RQ2)

For this analysis, we divided the messages into two sections. The first section was from the start of the class to the first trial of the integrated robot, during Week fifteen of class, and the second was from after demo 1 to the end of the class. Figure 1 a) shows the distribution of messages by team sent within each section.

More messages were exchanged in the second half of the course than in the first (3,455 vs 2,514). In both halves of the course, intra-team communication was more frequent than inter-team communication, but the proportions varied. In the first part, 76% of messages were within a single team, and in the second part, 68%. These results were expected since, at the beginning of the semester, the students were primarily working to solve challenges as teams. As the course progressed, however, integration of the components became an essential task.

Interestingly, the participation patterns of the teams were broadly similar in the two periods analyzed. The teams that exchanged a greater number of messages in the first half of the course were the same ones that had a greater exchange of messages in the second half. One major difference between sections of the course was that the communication was more diverse and evenly distributed in the second half. If SNA analyses had been conducted while the course was being taught, it would have provided valuable diagnostic information to the instructor. For example, the instructor could have intervened to elicit greater integration with the HARDW group.

Conclusions

To prepare students for a professional career, we must improve their preparation in communication and collaboration. To that end, we designed and implemented a course requiring intra- and inter-group collaboration course. The scarcity of tools available for the practical, real-time evaluation of CoP functioning led us to use the quantitative tool of SNA based on Slack messages. Applying CoP as a lens to interpret the results of the SNA allowed us to understand what kind of connections were developed between the teams and how the course functioned in general. Separating the data by date also allowed us to analyze whether and how the communication patterns changed across the semester. Our research introduces a general methodology which can be used by instructors to evaluate their class communication; diagnose specific issues such as isolated teams or uncommunicative individuals; and assess the fit to formal theories of team organization such as CoP. This in turn can support better classroom practices and timely interventions to allow the participation of all students and the appropriate development of collaborative skills. Finally, knowing the patterns of participation of the teams within the class will allow the instructor to design new or modified tasks for each team that allows generating team inter-dependency, supporting equitable participation for all.

Limitations and future work

The primary limitation of this work is that it takes place within a single course and was not evaluated across multiple classes. An additional limitation is that we were not able to capture the in-person interactions that took place in the classroom. While the classes were of fixed duration and were focused on seminars not team communication it is possible that some relevant communications were missed. We are researching subsequent iterations of this course, as well as other graduate engineering courses, in order to generalize our findings.

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