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ABSTRACT

This paper reports on lessons learned in implementing a pedagogical technique identified as Total Team Collaborative Learning with Swarm (TTCL – Swarm). In this technique, students are divided into small groups and are asked to complete a structured review of assigned material. The swarm aspect of this technique is inspired by swarm intelligence, a natural phenomenon in which individuals collaborate to achieve tasks as a group that could not be completed by an individual working alone. TTCL – Swarm is implemented in an Introduction to Operations Management class which is divided into large lecture sections with small accompanying lab sections. The instructor's experience with TTCL – Swarm and recommended modifications are discussed.

Keywords

Collaborative learning, Swarm, Large class size, Student groups, Operations management

INTRODUCTION

The ability to work effectively in a team-based setting is a critical skill for employees today. Tech giant Google recently released updated findings from Project Aristotle, a multi-year study that examined the characteristics of top-performing teams. They found that the most inventive and productive teams were not those made up of employees with the strongest technical skill set but rather those with the strongest teamwork skills (Strauss, 2017). Faculty, with the goal of ensuring students' preparation to enter the workforce, often turn to collaborative group work both to improve student learning outcomes and to provide students with the opportunity to develop important teamwork skills (Young and Henquinet, 2000).

In this study, we report on the lessons learned from implementing a swarm technique in a collaborative learning environment. The paper is organized as follows. First, we provide a brief overview of collaborative learning and its characteristics. Next, we provide background of the swarm technique and its intended use. We offer additional in-depth discussion of our experiences in implementing swarm including both problems and unexpected enhancements to the technique. Finally, we conclude with a discussion of next steps in this ongoing research project.

COLLABORATIVE LEARNING

Cooperative or collaborative learning is the situation in which students work in small groups towards a common learning goal. Demonstrated benefits of this approach include greater student interest in the subject matter (Du, 2015) and better student performance (Triche and Flamm, forthcoming; Santicola, 2015; Yamarik, 2007) as well as transfer, defined as students' ability to adapt knowledge to novel situations (Pai, Sears, and Maeda, 2015). Additionally, collaborative learning has been shown to improve important teamwork skills such as building trust among group member and constructive conflict resolution (Johnson, Johnson, and Smith, 2007), and improved communication and collaboration (Razali, Noor, Ahmad, and Shahbodin, 2017).

Social interdependence theory provides the theoretical underpinnings for collaborative learning (Johnson et al., 2014). This theory suggests that members of a group can be motivated to work towards a common goal when certain conditions apply. As expressed by Johnson, et al., "The essential heart of cooperative efforts is *positive interdependence*, the perception that one is linked with others in a way that one's success is not possible unless others succeed (and vice versa)" (Johnson, Johnson, and Smith, 2014, p. 93). A condition of positive interdependence can be encouraged by the establishment of mutual goals and mutual rewards among group members (Nolinske and Millis, 1999). For example, group scores may depend on an average of improvement of all group members or upon the score of a randomly selected member. Another condition for successful collaborative learning is *individual accountability* in which the performance of group members is assessed individually (Johnson et al. 2014). Such assessment may help to mitigate free-rider issues and may help the group to structure collaborative efforts to provide support for all members' learning.

Total Team Collaborative Learning

Total Team Collaborative Learning (TTCL) is the term given to our initial collaborative learning implementation ((Triche and Flamm, forthcoming). This approach has been implemented in ISQS 3344 – Introduction to Operations Management. This course is offered in large lecture sections of approximately 300 students with accompanying lab sessions of approximately 30 students. This course was chosen because both exam results and student evaluations for the course have historically been low. For several years, students in the lab sections have been asked to complete a group project which is intended to reinforce concepts covered in the lecture course. However, feedback from both students and faculty indicates that the project has not been a satisfactory method to help students learn and apply key topics. Therefore, the faculty member with primary responsibility for the course has developed and implemented TTCL in selected ISQS 3344 lab sections. Initial findings from TTCL implementation are reported in Triche and Flamm (forthcoming) and are summarized below.

The initial implementation of TTCL was in the form of voluntary study groups that met outside of class (Triche and Flamm, forthcoming). In this study, the students who wished to participate were organized into groups of 3 or 4 based on schedule availability. Students were asked to sign a commitment document indicating that they intended to participate regularly with their groups. No grade penalty was assessed for non-attendance but a small bonus was offered as an incentive. In the group meetings, students used the time to review relevant course material, discuss concepts, and work problems. The study used ANCOVA to evaluate exam results while controlling for student GPA; participants in the study group earned significantly higher exam scores than non-participants for all three semester exams ((Triche and Flamm, forthcoming)).

Total Team Collaborative Learning Incorporating Swarm

Encouraged by the results of the prior study, we decided to extend TTCL by incorporating a technique to increase collaboration between student groups. The concept of swarm intelligence has its origins in the observation of living things, such as birds or insects, combining efforts in a self-organized way to accomplish tasks that none of the individuals could accomplish alone. For example, termites working together are able to build large nests with complex internal architecture that ensures appropriate temperature and atmosphere for the colony (Garnier, Gautrais, and Theraulaz, 2007). Artificial Intelligence (AI) researchers have created swarm intelligence systems that allow human beings to interact together when making decisions. Such systems have been employed in a variety of contexts including prediction of Oscar winners (Cuthbertson, 2016), identification of biomarkers for lung cancer (Best et al., 2017), and the selection of optimal learning scenarios based on learner's preferences (Kurilovas, Zilinskiene, and Dagiene, 2014). Our implementation of swarm in the TTCL environment attempts to simulate the combination of knowledge on a very small scale. In short, the idea is to make a group of people much smarter as a team than as individuals. In the remainder of this section, we describe our initial implementation of TTCL with swarm and modifications that were made due to circumstances encountered during the semester. Lessons learned and recommendations are also discussed.

Figure 1: Illustration of a Pod in the Active Learning Classroom

We implemented TTCL – Swarm in selected ISQS 3344 lab sections during the Fall 2017 semester. All students enrolled in ISQS 3344 are expected to attend the lecture section and are responsible for their own notes and attendance. As opposed to the TTCL study reported previously (Triche and Flamm, forthcoming), we decided to incorporate TTCL – Swarm as a requirement for two lab sections: one section that was restricted to Honors students and one which was open to any students. Students in these sections participated in TTCL – Swarm in lieu of the group project completed by students in other sections. Implementing TTCL – Swarm in the scheduled lab sessions offered two benefits. First, it allowed the instructor greater opportunity to observe group interaction and make appropriate modifications. Second, it allowed the students to take advantage of technology installed in a newly available active learning classroom.

The active learning classroom is designed to support group collaboration. The room is configured with nine 5-seat pods each equipped with a large computer monitor. The technology allows up to four students to connect their own devices simultaneously to the monitor so their screens can be observed by the whole group. It also allows the instructor to capture the display of a monitor and project it to a screen that can be viewed by all students in the class. An illustration of one of the pods is shown in Figure 1. Figure 2 shows the layout of the active learning classroom.

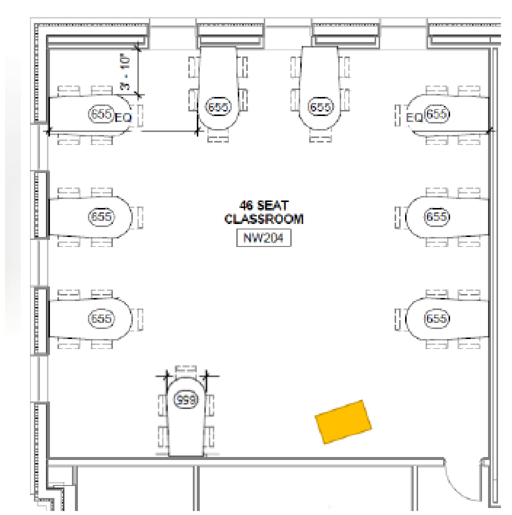

Figure 2: Active Learning Classroom Layout

In TTCL – Swarm, students in selected lab sections are grouped into teams of 3 or 4. In the lab session, students are asked to follow a structured process to review content from the lecture. The lecture review goes as follows:

- One member creates a cumulative document of notes taken by all group members and displays it to the monitor. Slides for the lecture presentation are also displayed.
- Member A discusses the notes he/she took on slide 1 and mentions questions that exist for him/her.
- All group members discuss the relevant issues until all questions are answered about Slide 1. Modifications based on group discussion are made to the cumulative notes.
- Member B then discusses Slide 2 in the same manner with group discussion to address open questions. This discussion continues until group members agree on a common understanding of the content for slide 2. If necessary, modifications are made to the cumulative notes.
- This rotation continues (Members C and D) until all slides are discussed and modifications documented in the cumulative notes.
- At the end of the lab session, each group should have a cumulative document that captures the knowledge and understanding of all group members.

The steps detailed above represent a single lab session. Our initial conceptualization of the Swarm technique was implemented in subsequent lab sessions as follows.

- In the next lab session, one person from each team (designated the traveler) takes a copy of his/her original team's cumulative notes and moves to another team. All teams will then review both cumulative documents developed in the previous lab session. The traveler works with his or her new group to create a new cumulative document that includes the insights and concept knowledge of both groups.
- Following the review and reconciliation of existing cumulative documents, the teams then proceed with the TTCL procedure described above to review content from the most recent lecture and incorporate it into their cumulative notes.

This process is repeated in the next lab session with different travelers moving from their original groups to new groups. In each lab session, groups review and reconcile the cumulative notes and then incorporate new material. After four rounds of rotation, the original group members will reunited. This review process continues after all lectures until an exam is scheduled. At this point, the cumulative notes document should contain a consensus of the understanding of up to eight people from two groups. All group members should have increased understanding of the relevant content based on having multiple opportunities to review and discuss that material with multiple teammates.

SWARM IMPLEMENTATION AND LESSONS LEARNED

The goal of TTCL – Swarm is to reduce out-of-class study time and maximize knowledge sharing within lab sessions. In this section, we report on the experience of the first semester of implementing TTCL – Swarm along with issues encountered along the way and suggestions for improvement in future semesters.

Role of the Instructor

During lab sessions, the instructor functions as both timekeeper and taskmaster. He or she offers explanation of the TTCL – Swarm processes and attempts to ensure that groups remain on task as they conduct their reviews. Having a monitor present during collaborative learning has been shown to have a positive effect on learning outcomes of group activities even if that monitor is only an observer and not an active participant (O'Donnell et al. 1986).

While having the instructor present in the lab may help to minimize off-topic activities, we observed a possible drawback as well. During labs, students tend to ask instructor substantive factual questions about course content rather than engaging in the work to discuss and determine answers themselves. In essence, this practice dilutes the benefit of the collaborative learning approach. Our observation is that such discussion may consume excessive amounts of the time that groups should dedicate toward review and discussion amongst themselves. Additionally, responses to such questions will only be available to one group at a time and not to the class as a whole.

Our recommendation, based on that observation, is that the instructor should carefully consider ground rules for interactions with students during lab sessions. One option might be to set time limits for answering substantive questions – perhaps 5 minutes per group. This approach may allow the instructor to keep groups moving forward without spending excessive time on relatively simple factual misunderstandings. It may also serve to address the issue of distracting the group from completing the work on their own. But, it would not serve to share the instructor's answers to substantive questions with other groups. Another option that could address both potential issues is to designate a time specifically for answering substantive questions with the class as a whole. Depending on the time available and the extend of the substantive questions, this time might be a few minutes at the beginning of each lab session or a longer time scheduled for the lab session prior to the exam.

Role of the Traveler

Based on the instructor's experience, the role of the traveler changed dramatically during the semester. The original concept was that one student from each group would travel to a new group each session. The process would be repeated in the next session with a different student from each group traveling to a new group. With four-person teams, the original starting groups would be reconstituted after four sessions.

However, the instructor observed a number of time-consuming problems with this approach. There was excessive confusion about procedural issues around traveling including: the determination of which group member would travel, where the traveler should go, and what the traveler was should do. Additionally, having travelers join new groups in each lab session contributed to excessive startup costs before the groups started work. These startup costs were both procedural and social. There was time spent introducing the traveler to other group members as well as time spent discussing the work approach. Both of these issues consumed excessive amounts of time that could have been spent on reviewing the assigned material.

After observing this problem over multiple weeks, the instructor implemented a modification to alleviate the observed issues. This modification was two-pronged. First, one person from each group was designated as traveler and that person served in that role for the remainder of the semester. Second, the time the traveler spent with the target group was limited to a total of 15 minutes during which groups were expected to review and reconcile cumulative notes documents. In his role as time-keeper, the instructor kept track of and informed the groups of when the travelers' time with target groups began and ended. In each subsequent lab session, the traveler visited the same group thus minimizing start-up costs and maximizing productive work time. The instructor observed that this change was effective in making the best possible use of the limited amount of time available in a lab session. Thus, it helped to serve the primary goal of ensuring that students were adequately prepared for upcoming exam.

However, there are also possible drawbacks of this approach that should be noted. One is that only one student from each group benefits from the experience of serving as traveler. The traveler must organize knowledge contained in the cumulative notes document in order to concisely explain and reconcile any differences in the given time period, thus helping to enhance his or her understanding of the material. Additionally, the designated traveler has the opportunity to practice interpersonal skills in interacting with the target group. While members of the target group that welcome the traveler are also interacting with a new group member, there are additional stresses associated with serving in a boundary-spanning role as the ambassador to a group other than one's own (Ancona and Caldwell, 1992). Designating a single group member to serve as traveler limits the experiential knowledge gained to only one person per group thus limiting the extent to which TTCL with swarm allows students to develop these important interpersonal skills.

Ideally, it would be desirable to allow all students in the class to serve as traveler but to do so in a way that optimized productive work time. We have multiple recommendations based on experience from the semester. First, we recommend that the role of traveler rotate among group members. However, we recommend that the travelers' time spent with target groups be limited. While some degree of socialization and introduction to a new group is an important component of developing interpersonal skills, adhering to a time limit may help students to resist the temptation to spend excessive amount of time socializing and maximize the productive use of that time.

An additional recommendation is to provide an ice-breaker activity early in the semester that serves two purposes. First, it would allow students the opportunity to engage in some of the desired socialization. Second, it would provide students with an opportunity to practice with the swarm process without the additional complication of reviewing course material. For example, during the first lab session, students could be randomly assigned to groups. Each group could devote a specified amount of time to engage in brief socialization. Groups could collaborate to prepare a document containing some personal information such as hometown and an interesting fact about themselves. The groups could then nominate a member to serve as traveler who would take that information to another group and practice with the swarm technique described previously. Each group could then briefly report a summary of information learned from the traveler to the class. Other options are possible as well, but this type of activity may help to set a positive tone for group interactions.

Document Inconsistencies

Our initial thought was that the TTCL – Swarm technique might provide benefits to students through the transfer of learning process best practices as well as knowledge of course material. In other words, in addition to student helping one another to gain greater understanding of the material they may also help one another gain greater understanding of study and review processes. However, the instructor observed that inconsistent approaches, specifically with respect to document formats, were a problem from the beginning of the semester and for the first several weeks. Some students arrived to lab sessions with hand-written notes, some with notes in Word documents, and some with notes on class PowerPoint slides. Reconciling these documents both within groups and between groups proved to be problematic. It was more difficult for the travelers to convey knowledge and for the destination group members to incorporate that knowledge when trying to merge from different types of documents. After the first few weeks, the instructor responded to this issue by advising all groups to maintain their notes in annotated PowerPoint documents. We recommend that this practice be adopted in future semesters.

Student Preparation

In addition to process modifications made by the instructor, one suggestion for process improvement comes from the students. Two high performing student groups experimented with and implemented their own process improvement. Specifically, these groups chose to sit together during the large lecture sessions and to take their initial notes on a shared Google Slides document. This document was created by saving the instructor-provided PowerPoint to the appropriate format. Students then collaborated to take notes, working simultaneously on the document during lecture. This approach allowed them to minimize redundancy in that initial document thus allowing greater time during lab sessions for analysis of course content. We recommend that instructors offer this suggestion to lab groups early in the semester.

Technical Difficulties

The lab sessions were held in the active learning lab described earlier. While the instructor's experience with the technology was generally positive, there were some issues observed with the technology. Students were often unable to connect their own devices to the shared monitor. In some cases, they were able to connect but subsequently were disconnected and unable to reconnect. Dealing with these problems cuts into effective work time and increases frustration levels for both students and the instructor. We recommend that instructors using similar technology implement two procedures to mitigate technical issues. First, request IT support assistance attend the first few lab sessions to provide appropriate training to both students and instructor and to troubleshoot problems that arise during those sessions. Second, develop and provide a specific backup plan in the event one or more students are not available to connect to the technology.

FUTURE DIRECTIONS

We considered the Fall 17 semester to be an opportunity to work through issues with this new pedagogical technique. Based on the lessons learned, we intend to implement the modified TTCL – Swarm approach with the recommendations discussed here in at least four lab sessions during the Spring semester. We also intend to continue collecting data to help evaluate outcomes of this process. Specifically, we plan to collect data regarding student satisfaction and exam performance in both TTCL – Swarm and traditional classes. At the time of the conference, we should be able to report initial anecdotal feedback from students and instructor observations about the modified implementation of TTCL – Swarm. Additionally, we should also be able to report on whether there are significant differences from the first test scores from Spring 2018 semester. Going forward, an extension to this research is to develop an instrument to help assess teamwork skills. A pre-test/post-test approach in which we evaluate teamwork skills at the beginning and end of the semester may help us determine whether TTCL – Swarm has the desired effect of helping students to develop that important skill set.

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