Benefits of Long Distance Collaboration in Higher Education Institutions to Train Students in Innovation Practices

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Benefits of Distance Education Collaboration in Higher Education Institutions to Train Students in Self-Learning and Innovation Practices

Abstract – The class described below is comprised of students from two universities, where students participate synchronously or asynchronously by attending twice-weekly scheduled meeting times either in person, viewing a live stream via an online conferencing tool, or watching recordings at a later time. This paper describes how students approached long-distance collaboration within teams compared to teams who met face to face. It further presents students' perceived benefits of developing the skills necessary to collaborate in online and distance situations, skills which will equip them to work, learn, and research in an increasingly virtual world.

An Innovation-Based Learning model was deployed to test how teams from multiple locations, termed as Multi-site teams, could produce deliverables in comparison to teams who met in-person. Our results show that location separation was not a factor in the success of student teams. This finding suggests, students and learners, who may not be able to participate in a brick and mortar university, can participate in innovation-based teams and the innovation-based learning culture. By increasing the inclusion of members, a diversity of mindset can be attained, which the authors believe may increase a team's ability to creatively solve current healthcare challenges.

Introduction

Rapidly Changing Career Needs

Educational researchers are working towards developing and integrating new teaching practices that equip students with experience in relevant technology, virtual workspaces, and multidisciplinary teamwork, alongside the technical skills necessary to thrive within the current global workplace [1]. Developing and instructing engineering students to be experienced in the above-mentioned qualities and also thrive within the biomedical field is a daunting task requiring a creative solution. One successful solution is business integrated teaching and learning techniques where engineering students team with medical professionals to experience shortcomings faced by doctors, nurses, and healthcare providers [2]. However, this model requires engineering students to have access to hospitals or clinics with willing practitioners to act as mentors, and not all Higher Education Institutions (HEI) offering degrees in biomedical engineering have this type of access.

Researchers and industry have also called for graduating biomedical engineers to have experience working in multidisciplinary teams that meet virtually to develop innovative solutions [1], [3], [4]. An initiative for industry-academia teaming together for student development is the Partners for the Advancement of Collaborative Engineering Education (PACE) program where companies such as Siemens PLM, Hewlett Packard, and General Motors collaborate with ABET-accredited academic institutions to provide state-of-the-art technology access and opportunities for students to work on real-world problems during their undergraduate education [5]. The PACE program has a portfolio of teams that include students located in various countries, from multiple academic institutions, working together virtually and globally to innovate and create products for market consumption. This model has been successful during its lifespan by preparing students for the global workplace [5]. Another useful industrial model for creating an innovation-based work atmosphere is Lean Startup. A Lean Startup model includes quickly brainstorming solutions, building prototypes, taking measurements, and learning what did and didn't work for future project iterations. This model works by making ideas into products quickly and efficiently [6]. Finally, there are also academically focused innovation-based curricula that have been used by initiatives such as the Biodesign Innovation Process. The Biodesign Innovation Process works through three phases: trying to quickly assess relevant needs in the healthcare field, inventing solutions to these needs, and creating prototypes of the inventions [7].

The Innovation-Based Learning Model

In a complementary model, termed Innovation-Based Learning (IBL), our team has developed and implemented a cardiovascular engineering course, which provides students with experience working in multidisciplinary, multi-university teams via online and distance education collaboration [8]–[12]. This instructional model's central focus is to create a classroom environment in which students have the freedom to learn, test, and design creative solutions to current cardiovascular engineering problems. Another key element of the model is it allows students to set personal learning objectives, perform project management on these objectives, and grow in cognizance of driving personal learning. Students in this cardiovascular engineering course consist of both undergraduate and graduate students from two universities and one university's distance education program.

In the IBL model, students select current biomedical challenges to pursue, which may be identified on Funding Opportunity Announcements (FOAs) published by federal agencies such as the National Science Foundation (NSF), the National Institute of Health (NIH), businesses, and industrial groups. Students research an FOA that holds personal interest to them and students are in control of which challenges are pursued while instructors act as mentors and coaches to help students grow [9]. Students are entrusted with a great amount of freedom: from choosing which problem(s) to tackle and pitching their ideas, to recruiting other classmates to join their team, setting up meeting times via online conferencing tools, and working together to create deliverables from various locations across the U.S. [10]. This model aims to produce quality deliverables, which students can own as their personal intellectual property and innovation. The journal publications, poster presentations, business plans, outreach activities, invention disclosures, awards, and products developed are among the deliverables students can produce [8]. The students gain experience working within a team that includes students from other majors, universities, backgrounds, and geographical locations all gathered in one class. Overall, the Innovation-Based learning model provides a course structure that encourages multi-university, online collaboration while still maintaining high caliber, student-driven projects all to provide well-trained, innovative students ready to excel in the global workplace.

Goal of Research

The goal of this study was to determine if multi-site groups (i.e. some members able to meet in-person with other members online-only), who collaborated completely online, could be as successful as groups who were able to collaborate in-person, while also meeting all course objectives. Factors that contributed to the success of online-only teams (e.g. tools, skills) are also identified based on the results of a post-course survey.

Methods

Class Structure

In the pilot study of the innovation-based cardiovascular engineering course there 35 students who split up into 9 teams. These teams ranged from having 2-6 members. Students enrolled in the class were from North Dakota State University (NDSU) campus, University of North Dakota (UND) campus, or University of North Dakota's Distance Learning (UND-DL) program which was a distance education program consisting in students enrolled in UND but only participating online. Table 1 below shows the breakdown of the number of teams and the combination of universities/programs they enrolled in. NDSU and UND are both Division I, public, research institutions within the range of 10,000-20,000 students. Students consisted of both undergraduate and graduate students from NDSU, UND, and UND-DL (being online only students from UND). 28 students agreed to participate in the study with the following breakdown: 13 undergraduate seniors, 3 Masters students, and 11 Ph.D. students (1 student did not provide a program level). 22 students were male and 6 were female, with the mean age of the class being 26.5 years old. A variety of majors and programs were also represented in the sample; 9 students were in Biomedical Engineering, 9 in Electrical Engineering, 5 in Mechanical Engineering, 4 in Computer Engineering and 1 in Health, Nutrition, and Exercise Science.

The cardiovascular engineering course is offered as a senior/graduate-level class but is not limited to these student populations. The course uses an accumulation of fundamental electrical and mechanical engineering concepts, along with cardiac physiology and anatomy concepts. The students were able to pitch a solution to an FOA cardiovascular engineering challenge and try to persuade other classmates to join their team. The instructors tried to ensure every group had between 3-5 members. However, at the end of the team formation process, one team only had 2 members and another team had 6 members. After meeting with these teams individually, it was determined that both teams had planned an appropriate amount of work to accomplish for a semester class, and were therefore allowed to proceed.

<table>
<tr><th>Team Type</th><th>Total of Teams</th><th>Team Legend</th></tr>
<tr><td>NDSU</td><td>4</td><td rowspan="5">NDSU = campus 1
UND = campus 2
UND-DL = distance education from UND participating online only

Each team has between 2 - 6 members</td></tr>
<tr><td>UND + UND-DL</td><td>2</td></tr>
<tr><td>NDSU + UND-DL</td><td>2</td></tr>
<tr><td>NDSU + UND + UND-DL</td><td>1</td></tr>
<tr><td>Total Number of Teams</td><td>9</td></tr>
</table>

Table 1. Students broke themselves into teams that looked like the following: four in-person NDSU teams, 2 mixed UND in-person/UND-DL distance education teams, 2 NDSU in-person/UND-DL distance education teams, and 1 NDSU in-person/UND in-person/UND-DL distance education team.

Cardiovascular Engineering Course Objectives

Previous iterations of this course have been offered solely at NDSU, but the instructors wished to test the feasibility of working with a second university while also adding distance education students. Therefore, course objectives were made similar to previous semester offerings to understand and observe how students were able to work in a mixed asynchronous/synchronous setting. The main course objectives set by the instructors include: obtaining a basic understanding of cardiovascular engineering concepts, applying the cardiovascular engineering concept knowledge to current real-world problems, professional skill development, and increasing empathy for the needs of others and the cardiovascular engineering field. A brief discussion of whether these course objectives were meet will be discussed later in the Results section. The authors hypothesize that diversity of mindset, academic expertise, and content background within a team will lead to an increase in innovative solutions produced.

With plans to scale-up the offering of this course to a larger audience of students in future semesters, the authors were interested in learning whether students would be able to be successful in multi-site teams that had some members able to meet in-person and others only able to meet virtually. Therefore, to test the scalability of this model, the revised course was offered to students face-to-face (F2F) from two universities (i.e. NDSU and UND) and also through a distance education program (i.e. students from UND-DL). Based on the data gathered from the successes and failures of multi-site teams in this pilot study, the authors will revise course instruction for future course offerings involving students taking the class from multiple universities and colleges.

Team Formation Process and Team-set Learning Objectives

At the beginning of the semester, students were asked to individually find an FOA from NIH, NSF, or an equivalent funding agency, for a current cardiovascular challenge that the students were motivated to work on. All students were asked to pitch their chosen FOA and proposed solutions in a one-minute video clip. Students joined a group of their choice after viewing the video pitches. After a group was formed, each student was tasked with writing his or her learning objectives. These learning objectives were items the student would learn while working on the semester project. Students were expected to work in teams and provide bi-weekly progress updates on personal and team learning objectives and milestones. Finally, students were asked to log their individual learning objectives and progress on an online class platform. Through logged data on the course platform and an end-of-class survey, the instructors-made observations about how students' location affected their ability to deliver innovative solutions within their chosen team project.

Metrics of Success for the Innovation-Based Learning Model

The metrics used to assess the effectiveness of this model have two parts; 1) students make sufficient progress in meeting course objectives and, 2) full engagement in the innovative process. This is fulfilled by students' creation of innovations and deliverables that hold high external value. Using the guidelines of the World Intellectual Property Organization's definitions of innovation and intellectual property stating an "*Innovation is a means of doing something new that improves a product, process, or service*," and this innovation has to be "*novel (new), useful, and non-obvious to someone working in a related field*" [13]. Here the authors define high external value as products that have the ability make an impact globally or societally. Examples include products such as invention disclosures, journal publications, business pitches, awards, invited outreach activities, etc. Or in other words, products of high external value have an impact outside the walls of the classroom and have received expert review and feedback.

Since students keep online learning portfolios, the number of deliverables being created by students can be tracked along with progress completion and evidence of students' contribution and work. At the semester's end, the two main in-class instructors and four additional members of the instructional team independently assessed each student's work according to the external value rubric shown in Table 2. Upon completion of individual assessing, the instructional team compared student assessment and collectively agreed on a student's grade. The goal of this practice was to reduce any student grading bias and increase the claim of a fair grading scheme.

Low Impact (in-class impact only)	- Test - Quiz - Homework - In-class survey
Medium Impact	- Standard operating procedures - Providing expertise to other research groups - Non-refereed conferences
High Impact	- Invited outreach activities - Refereed conferences - Refereed journal manuscripts - Scholarships - Awards - Invention disclosures - Business pitches - Business plan competitions

Table 2. Above are examples of end-of-semester products that students can submit as deliverables as evidence for their final grade. These deliverables have been broken down into impact levels labeled as low, medium, and high.

Finally, at the end of the semester, students were surveyed using an IRB-approved 34-question survey containing: open response, and 5-point Likert scale questions. This survey is also used as a metric to assess the overall student perceived success of their team.

Results

Student Perceptions of Team Success

The survey results include 24 student responses from a class size of 35 students. Of the 24 student responses, 10 were from students who participated in a multi-site team and 14 were from students who participated in a F2F only team. As previously stated, students formed teams based on similar interests and FOAs put out by a federal agency. Below, in Fig. 1 and Fig. 2, are students' perceptions of their group's collaboration and completion of learning objectives.

To determine if there were significant differences in the student attitudes of group success based on being a member of a F2F versus a Multi-site team, a student t-test was used to compare these two populations for both Questions 10 and 11 (stated above). By setting the significance level of $p < 0.05$, the null hypothesis, H_o, that there were no statistically significant differences between the sample groups of F2F team member and

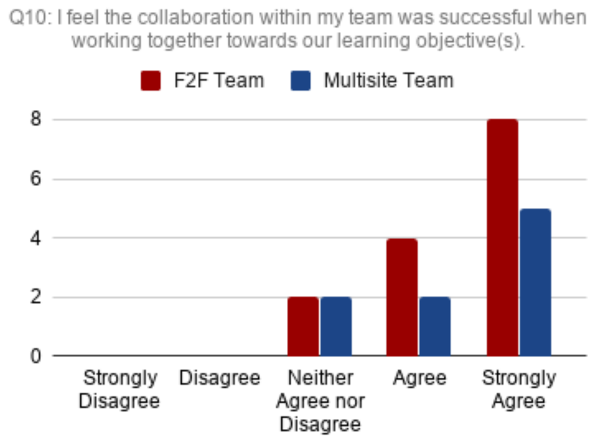

Figure 1. 56.5% of students who responded to the survey strongly agreed that the team collaboration was successful in their group. This response is seen from both F2F Only and Multi-site teams. Note: one student did not choose to put any response to this question. So the total number of answers is 23.

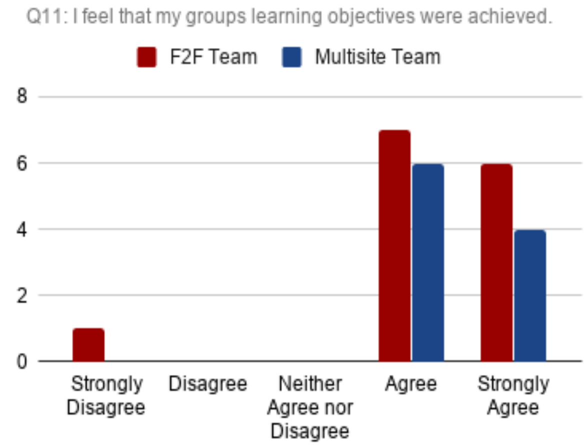

Figure 2. All survey responders, with the exception of one individual, perceived their team to have achieved the group's learning objectives by the end of the semester.

Multi-site team member responses were tested. Table 3 (below) displays the resulting means, standard deviations, and whether the null hypothesis was accepted or rejected. Based on these results, we conclude, both students on F2F teams and Multi-site teams perceived their team to be successful in collaborating and accomplishing learning objectives.

Survey Results			
Question 10			
F2F	*Mean =4.4286 (out of 5)*	*Standard Deviation = 0.7559*	*Fail to reject* H_o, *with* $p<0.05$
MS	*Mean = 4.3333 (out of 5)*	*Standard Deviation = 0.8660*	*Fail to reject* H_o, *with* $p<0.05$
Question 11			
F2F	*Mean = 4.2143 (out of 5)*	*Standard Deviation = 1.0509*	*Fail to reject* H_o, *with* $p<0.05$
MS	*Mean = 4.40 (out of 5)*	*Standard Deviation = 0.5164*	*Fail to reject* H_o, with $p<0.05$

Table 3. Students in both Face-to-face teams and Multi-site teams had similar perceived attitudes towards successful group collaboration and the achievement of learning objectives. Above shows the mean and standard deviation to the responses of Questions 10 and 11 on the end-of-semester student survey. Based on performing student t-test with a p<0.05, it was determined that no differences in the answering based on team types were able to be identified.

Tools Used in Team Collaboration

Students in Multi-site teams attributed their successful completion of deliverables to several tools and skills. When asked on the survey, "*What skills and/or tools help your team overcome the difficulty of distance to successfully create deliverables*," G Suite/Google Drive was included in 70% of responses. Other popularly used tools were Slack, Zoom, and GitHub. Top skills, identified in the survey, for making an online collaborating team successful was: clear communication, good scheduling, an open mindset, and listening to other members.

Student Submitted Evidence for Course Objective Learning

These end-of-semester student perceptions agree with evidence provided to instructors on the online MOOCIBL course management platform. Of the 35 total students, 27 gave permission via an IRB protocol to have their online data entry tracked in MOOCIBL. Through MOOCIBL all progress towards completing student-set learning objectives was compiled by the authors. Based on supplied documentation and evidence on MOOCIBL, 74.1% of students demonstrated sufficient knowledge of basic cardiovascular engineering concepts, which was the foundational course objective. To break this down, 81.8% of students who were members of Multi-site teams and 68.8% of members of face-to-face teams demonstrated sufficient cardiovascular engineering knowledge. Sufficient knowledge was determined to be fluent in cardiovascular engineering terminology and demonstrate an understanding of concepts such as pressure-volume loops, arteriole modeling, and physiology of the cardiovascular system. If the student only chose to submit this evidence (no teamwork or innovation), the student would have received a C letter grade. However, if the student provided evidence of teamwork and innovation, but chose not to submit evidence of basic cardiovascular engineering concepts the student was penalized with the deduction of one letter grade.

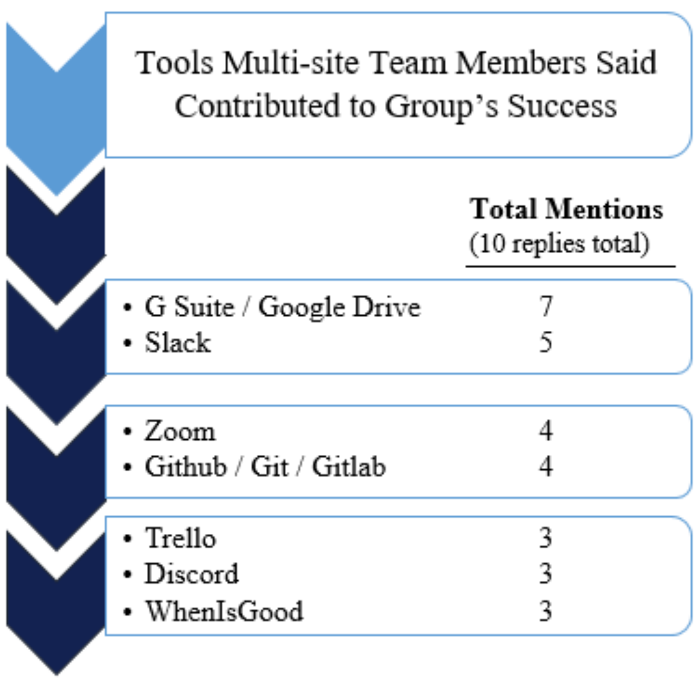

Figure 3. Google Drive was the most popular tool multi-site teams attributed their success to. Other project management applications such as Slack, Zoom, and GitHub were among the top responses. Overall, these teams used a variety of file sharing and repositories, scheduling, and online communications tools.

Evaluating Student Work to Determine Impact of Team Innovations

To fulfill the third course objective, stated on the syllabus, students were required to submit electronic copies of evidence (ie. papers, emails, files, etc.) to display their growth, progress, and milestones of creating an innovation. At the end of the semester, all evidence submitted by students was ranked into external value categories of low, medium, and high impact based on the rubric set in the syllabus. For clarification, external value with low impact would be defined as a product that only benefits the student personally or members of the class. In comparison, a high impact deliverable would be defined as a product, activity, or work that has received an expert review and has been shared publicly. Examples of high impact deliverables, shown above in Table 2, include but are not limited to: referred conferences and/or journal manuscripts, patents, business pitches, awards, scholarships or fellowships, invited outreach activities, or invention disclosures. Ultimately, grades were assigned to students based on the submitted evidence's level of impact.

The cardiovascular engineering class had a total of 4 F2F teams and 5 Multi-site teams ranging from 2-6 members per team. To analyze Multi-site teams' ability to engage in the innovation process and create products, compared to F2F only teams, high impact deliverables were tallied up according to teams. After charting, located in Table 4, the high impact deliverable amounts per team, some conclusions can be made.

Based on the results shown, all teams produced at least one high impact deliverable, although not all members of a team consistently contributed to the high impact. Also, all F2F and Multi-site teams were able to complete between one - four high impact deliverables by the end of the semester.

End-of Semester Deliverables (per team)					
F2F Teams			Multi-site Teams		
Team	Deliverables	Total # of Deliverables	Team	Deliverables	Total # of Deliverables
A	Published educational website	1	A	Conference paper	1
B	Business plan, conference paper	2	B	Patent application	1
C	Invited outreach activity, published an informational brochure	2	C	Grant proposal, conference paper	2
D	Conference poster, conference competition award, innovation challenge award	3	D	Conference paper	3
			E	Filed provisional patent, conference paper, marketable product	4

Table 4. The 9 teams produced a range of high impact deliverables. Student teams were able to assemble, produce innovative products to deliver evidence of items such as conference papers, awards, business plans, and provisional patent applications, all within 1 semester.

The deliverables produced by students, shown in Table 4 suggest multi-site teams' inability to meet in person did not hinder them from producing quality deliverables by the end of the semester. There were one F2F and one Multi-site team able to complete a grand total of 4 high impact deliverables as a team. In contrast, there were F2F and Multi-site teams who only completed 1 high impact deliverable as a team. These results suggest other factors affect and determine a team's overall prosperity. Per instructor observation, additional factors that contribute to a more or less successful team may include graduate to undergraduate member ratio, personal background/experience, personal motivation, lack of direction on the team project, time/lack of time based on personal semester course load.

Changing Personal Perspectives

This course model also aims to meet the objective of helping students become more empathetic to the needs of others and the cardiovascular engineering field. Students adding value to academia and industry through new products, knowledge, and motivation, are already practicing what it takes to solve global grand challenges. A free-response question on the survey asked students to note something that the class inspired them to do better or differently. One student's reply included: "*The class has inspired me to believe in myself and my abilities. The amount of innovation this class has produced has given me confidence that all things are possible, while at the same time, failure is not essentially a bad thing,"* and a second said "[to] *publish my work in a more open but still casual way."* The student testimonies provide evidence that this course model and classroom environment have led to accomplishing the final course objective and aided in the development of socially conscious engineers and problem solvers.

Discussion

Since this was the pilot study and the first attempt at up-scaling an Innovation-Based course there is still much room for improvement and refinement within this model. At the beginning of the class, there were many technical difficulties to overcome so that smooth online communication could take place between the two separate universities and multiple distance education students trying to connect during a scheduled class meeting. Making class-meeting recordings with good quality sound and video, as well as finding an environment to host the in-class participants while simultaneously allowing for distance students to view and participate asynchronously were other difficulties that took a few trials before a viable solution was found. These preliminary difficulties were noted in some student survey responses as factors, which detracted from the quality of the course and made it appear to have a lack of organization on the instructors' part. For the next iteration, we will have these issues resolved for a better class flow. The goal of the next iteration of this course is to expand the course offering to more universities and an increased audience of synchronous and asynchronous distance education students.

Conclusion

Based on the findings in this pilot study using the IBL classroom model, we observed students working on multi-site teams were just as successful in accomplishing team and instructor set course objectives as students who participated in teams able to meet face-to-face. The evidence gathered in the MOOCIBL platform shows that students on both types of teams were able to produce deliverables believed to have high impact and external value beyond the classroom based on the rubric set in the course syllabus. These deliverables include: a patent application, journal and conference papers, competition awards, and invited outreach presentations, just to name a few shown in Table 2 and Table 4.

The results suggest Multi-site teams are as capable of being successful as F2F-only teams. This is an exciting finding because it opens the possibility for students, who may not otherwise participate in online learning, to now join an online team. In the future, students with limited access to higher education but having internet access may have an opportunity to join a team and work toward solving current healthcare challenges, just as the students in this class did.

Although students got to choose their own path through this course, the majority of students rose to the challenge and were successful in meeting the course objectives, alongside personal and team learning objectives. The results of this pilot course study lead us to believe further up-scaling of the course will be worthwhile and is planned for the next iteration of this course happening in Fall 2020.

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