Developing and Applying an Undergraduate Cross-course Team Assignment

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Abstract— **This Innovative Practice work in progress paper presents the efforts to integrate a group assignment between two construction related courses (one related to mechanical construction and the other to construction plans and measurements). With the increase in collaborative based project delivery in the US construction market and the acknowledgement that communication and collaboration are key to successful projects, the need arises for the use of student projects with an emphasis on these collaborative skills. However, experiences in cross-course assignments, or shared activities between courses are still scarce throughout the curriculum with few reported experiences in the technology and engineering technology fields. In this paper, the authors present a pilot experience in developing and piloting a cross-course collaborative, student centric project that raises awareness of the importance for teamwork during problem solving situations in the construction industry. The creation, roll-out and assessment of this assignment will be outlined in the paper, as well as potential steps and suggestions for improvements to this project or similar assignments in the future so that other instructors considering cross-course projects may take these suggestions into consideration.**

Keywords—problem-solving; teamwork; undergraduate education; problem-based learning

I. Introduction

Lately in the United States construction industry, we are seeing a rise in the use of alternate, and more collaborative delivery methods, such as Design-Build (DB) and Integrated Project Delivery (IPD). These have come as an alternative to more traditional delivery methods (e.g.: Design Bid Build) and as a way to reduce adversarial tensions during the project process [1]. The increase of collaboration between contractors and designers or contractors and several stakeholders is a way to reduce the fragmentation of goals that currently exist in the construction industry. However, researchers indicated that "many of these attempts have not fully achieved the expected success, probably because they are frequently superimposed onto environments where adversarial cultures and attitudes still exist" [2].

Previous studies in industry have already identified communication and collaboration as key to the success of a project [3, 4, 5], but the rising interest due to DB and IPD has renewed the discussion of how to help students acquire effective communication and collaboration skills during their college education. Both the American Council for Construction Education (ACCE) and the Accreditation Board for Engineering and Technology (ABET) have included learning outcomes related to teamwork and effective communication as part of the required skills for undergraduate construction management or construction engineering education [6, 7].

With this call for collaboration and communication in both major accreditation bodies that serve construction management and construction engineering programs in the United States, several instructors have presented their experiences with creating collaborative activities for students. These experiences display how broadly collaboration and communication can be implemented in the curriculum, be it through competition teams [8], international collaboration experiences [9] or required courses [10, 11]. However, not only has previous literature identified the potential benefits of teamwork and problem based learning, but also the challenges of doing so. Challenges to course collaboration in construction management are also similar to other engineering disciplines and involve finding real world scenarios, difficulties with faculty collaboration and an increased work load [10, 12].

Current educational pedagogy also has influenced how important content is, when presented to students at the undergraduate level. Purdue University has lately increased its effort to provide more meaningful learning to students by focusing on ten key elements, some of which are: theory based applied learning, team project-based learning and integrated learning-in-context curricula. Within those key elements, a special emphasis in the transformation is given to active learning experiences within courses, as well as student centered learning. Student centered learning environments involve active learning, as well as more accountability and collaboration between students [13]. Project Based Learning (PBL) can be considered a student centered learning method focused on real world and open ended problems, with the goal of improving knowledge and social and technical skills [12].

Based on the call for transformation, we have piloted a cross course assignment, presented in the present paper. We will discuss the conception and application of a horizontal assignment integration between two required sophomore courses in construction management at Purdue University - a plans and measurements course, with focus on plan reading and quantity take off, and a mechanical construction course, with focus on the introduction of mechanical components and uses within a construction project – during the Spring 2017

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semester. The assignment consisted of group work around an open ended scenario, involving a mechanical concern. Institutional Review Board (IRB) exemption was obtained under the # 1704019110 protocol.

II. Assignment Design

When developing the learning experience, we wanted students to approach the learning experience using problem based learning and collaboration. The main goals of this activity were to: (1) implement a collaborative experience between two courses in a low stake exercise; (2) evaluate available technologies to host the exercise; and (3) evaluate students' impressions of collaborating with students from different classes.

Based on these goals, we decided the activity should be related to providing solutions to a concern expressed by a construction stakeholder. For this reason and to match the requirements of the courses, the problem should involve some type of plan reading and mechanical construction components. The plan reading course already used the complete set of bid drawings for a fire station in Central Indiana as a background for plans and measurements, as well as practical activities such as information searching and quantity take-offs.

Because students are not used to working with other classes in a collaborative homework assignment, we chose to implement two ten day instances (problem prompt #1 and problem prompt #2, presented in table I) of the exercise during the Spring 2017 semester as a pilot experience. To serve the purpose of both classes, the problems needed to have similar components of plan reading and mechanical construction recognition/understanding. Furthermore, the prompts developed required students to evaluate the information and verify if the concern is valid or not.

TABLE I. Problem Prompts 1 and 2

Problem Prompt 1 (P1)	Problem Prompt 2 (P2)
There is an issue regarding the rooftop condensing units; the owner fears that these units will be visible from the street, showing above the parapet wall. Please acknowledge the units in question, the height of the different components, the potential visibility, and locations of said components. Remember, your team is to supply four potential "fixes" for this potential problem and then a recommendation for your prescribed fix.	There is an issue regarding the plumbing above the Data Room; the Owner has concerns that a failure in this area could have dire consequences for the expensive equipment housed in the Data Room. Please identify the area of concern, the various plumbing lines and four (4) potential "fixes" for this potential problem. Please remember that your team is to convey all of this information to the Owners as well as the recommended "fix" as determined by your team. Please note that the project is currently in the framing stage; the foundation is complete and the main floor walls are being framed.

Students worked in teams of five students, assigned by the instructors. A 3-page problem prompt was presented to the students containing the problem context, problem prompt and evaluation criteria in the release of each assignment. Students were evaluated similarly for both iterations of the exercise and the grades were included as homework grades in both courses. Students were evaluated for their meaningful participation in the group as reported in the course management system (10 points, individual grade); for putting together a matrix of pros and cons for 4 possible solutions (10 points, group grade), and for issuing a final recommendation to the party that raised the concern (5 points, group grade). The instructors did not evaluate for the quality or accurateness of their solution, but rather completeness of the information required. Students were also warned that their solution would be shared with other students after the assignment was over. After each iteration, students were asked to complete an online survey about the exercise (which was worth 2 points), and in this online survey, they were shown all groups' final recommendation and voted for which they thought was best.

As a first challenge in the implementation of the exercise, instructors had to deal with creating different roles for students who were enrolled in both classes in order to make sure the assignment met the goals for the courses they were registered. A total of 88 students were involved with the assignment, of those 18 were taking the plans and measurement course, but not the mechanical construction course, 32 were taking the mechanical construction course but not the plans and measurement course, and 38 students were registered for both classes. Under these constraints, students who were registered for the plans and measurement but not for the mechanical course were given the roles of general contractors, students in the mechanical course, but not in the plans and measurements course were given the role of mechanical contractors, and students enrolled in both classes were given the role of designers, with years of construction experience.

Another challenge faced by instructors was to choose a common platform to receive and assess students' work. Both courses used Blackboard as the course management system and instructors wanted to continue to use the same platform so as to not require the students to learn and manage a new system. In Blackboard, a blended course was created including all students that were currently enrolled in both courses. Group pages were set for each group, and students were encouraged to use discussion boards on the course management system to hold discuss. Alternatively, the students could hold meetings and then record the meeting minutes. This feature was used to assess students' participation within their groups.

III. Review of Students' Work and Impressions

A. Problem 1 (P1) – Students' Work

For problem P1, sixteen of the eighteen groups submitted work. Of the initial eighteen teams; eleven chose to provide some insight into the problem using the discussion board feature on the course management system, seven groups decided to meet in person and provided their meeting minutes on the discussion board, six groups only used the discussion board feature to obtain contact information for either meeting in person or using other applications. It is important to note that the authors could not assess the interaction between students on applications other than what was reported on Blackboard (through discussion board or upload of meeting minutes).

Students' submissions varied substantially – from a simple one paragraph response, without headings or signatures, to formatted business letters with headings, contact information, and visuals (photos, drawings). Only one team provided a solution that matched the ideal solution thought by instructors: due to the height of installation of the condensing units and height of the parapet, the units will not be visible from the street level. The following is an excerpt from this group's recommendation letter to the owner, which also included street view pictures of the building:

> *After extensive research, we came to the conclusion that the owner does not need to be worried about the rooftop condensing units being visible from the road. As seen from the pictures below, there is no evidence of air conditioner units on top of the roof. When we looked up the model numbers of the units, the largest unit was 45" tall. The east wall of the fire station is 33' ¼" and the units sit at 26' 8". The west wall is on an arc with the shortest elevation being 30'. These walls are tall enough to block the units from view from the road since the units are located in the middle of the roof. Since the owner will not be making any changes, there will not be a cost to this solution, which means the taxpayers of [removed] would be saving thousands of dollars.* (extracted from students' solution proposal)

Students who voted in the peer assessment chose the group represented in the extract above as the best feedback to the owner (9 of 57 voting students, or 15.79%). Solutions suggested by other groups were: increase parapet height (7 groups); hiding units behind a new construction element (5 groups); increase wall height and change unit type (1 group); move units further into the roof or to new location (2 groups).

B. *Problem 2 (P2) – Students' Work*

For P2, all eighteen groups submitted work. A discussion board for P2 was also created in each of the groups' page on the course management system. In between assignments, instructors stressed the importance of providing evidence of meeting minutes if students met in person or used other technology to discuss the problem. However, for this submission only six groups used the discussion board to address the problem and potential solutions, four chose to only submit meeting minutes through the discussion board, and one group used blackboard just to mention all participants should be graded equally in participation, but there was no mention of how the contributions were made. Seven groups did not use the discussion board for working through the problem or submit meeting minutes, although some included the minutes with their solution matrix on submission.

Once again, the quality of submissions varied from a mere one paragraph with no formal formatting to formal business letters, addressed to the owner and on company letterhead. Two teams included visuals (photos) in addition to written content. For this problem prompt, several ideal solutions were envisioned by the instructors such as reorganizing certain rooms on the second floor or a leak proof, drop ceiling. The following are the solutions presented by the groups: specify a leak proof equipment or ceiling (6 groups); re-route piping around or below the room (4 groups) – this solution still does not deal with the floor drain from shower in the room above the data center; do nothing (rely on company's quality assurance and control processes) or get water insurance (2 groups); swap the data room (first floor) with another room in the building (4 groups) – either a storage room on the second floor, a storage room on first floor, the electrical room, or a bathroom; adding shut off valve (1 group).

Fifty-one students voted on the peer evaluation and chose the group who proposed the specification of a leak proof data center equipment as the best feedback to owner (13 or 51 voting students – 25.49%). This team also include a picture of the equipment and initial costs for it as shown the following extract from this team's recommendation.

> *After much research and deliberation, our design team came to the conclusion that the best solution to the owner's concern would be to purchase a waterproof* […] *server cabinet for each server in the Data Room. This eliminates the need to change the floor plans while completely protecting the expensive servers, ensuring the safety of the station's data. While carrying a hefty price tag of $4,500, the* […] *Server Cabinet comes equipped with its own cooling system. This eliminates the need for any previous cooling system included in the original design for the Data Room. It also seals against water, dust, etc. and prevents any outside air exchange from outside the unit. It also protects equipment inside to 8,000 BTU in case of a fire. The price difference would be minimal, with a possibility for a lower total cost.* (extracted from students' solution proposal)

C. *Survey Results*

As mentioned previously, students were asked to answer a survey at the end of each problem prompt. Fifty-seven students answered the survey after problem prompt 1 (P1), and 51 answered after completing problem prompt 2 (P2). Survey results showed that almost half of the students (%) felt workload was equally distributed in problem prompt 1.

As part of the survey, three statements pertaining to group work were presented for students to verify how much they agreed with said statement. The first inquired about distribution of work load among team members. A great part of the students (49% for P1 and 43% for P2) indicated they did not agree nor disagreed with the statement, however students that disagreed with the statement increased for P2 (from 22% in P1 to 27% in P2). Working as part of a team was enjoyable for most of the students (with 68% of students agreeing or strongly agreeing in P1 increasing slightly to 71% for P2). However, the perception of students learning more as part of a team rather than by themselves was shown to be only slightly more than half of the students (56% of students agreeing or strongly agreeing for P1 and 55% for P2). The amount of students who neither agree nor disagree with the previous statement increased from 26% in P1 to 33% in P2, which might be a result of the instructors not debriefing the assignment thoroughly enough.

Students were also asked about other platforms for group communication that they would suggest for future, collaborative assignments. Many of them mentioned the course management system worked well, but the survey also indicated that students would like to work (or have worked) on Google Docs, a real project management system, GroupMe, group text, regular email.

Additional comments made by students in the survey are summarized in table II. This included things students liked and what could be improved in the assignment, after the second iteration. Students also mentioned that homework points were weighted different for each class, which caused an imbalance of motivation between students of the different classes.

TABLE II. SUMMARY OF STUDENTS' PERCEPTIONS OF ASSIGMENT

Liked	To be improved
• Work through the problem solving process • Working as a group • Bringing two classes together • Thinking about pros and cons, brainstorming and providing solution • Real world problem • Seeing other groups work and learning from their submission	• Let students pick own teams • More in class contact with team • Have peer evaluation of team members • Increase scope or reduce team members • Not combine classes • Make problem more challenging • Use real issues and then show actual solution • More time to work on assignment

IV. INSTRUCTORS' IMPRESSIONS

For a first experience, we consider that the outcome was positive and both instructors have agreed to continue the efforts in developing cross course assignments. Developing the problems for students was not so much of a challenge, but rather making sure it would cover the content from both classes was. Also, the online management of this exercise was more difficult than expected as we had to request special help from the technology department in order to make sure all students from both classes would have access to the system. This was also a focus of complaint by students, as they would have to go to a second course to submit their assignment for this exercise.

In addition, some groups experienced issues with their team dynamics and were unsure of which instructor to ask for help – which sometimes resulted in students reaching out to only one instructor, or to one, and then the other. Team communication also was a struggle for teams, even though each team had a group page set up for them in the online course management. Some groups were very effective in using that platform, but others seemed to be unsure of how to contact classmates and work through finding meeting times for the group to discuss the assignment in person.

Finally, we were happy with the efforts made by the students to provide a realistic solution to both problems presented. However, it was clear through the solutions provided to problem 1 that students lacked the ability to correctly investigate and frame problems. Also it was noted that some students still lacked a professional vocabulary to address and explain the problem to clients, although this could be explained as this was a sophomore level class.

V. DISCUSSION

Through the students' feedback it was clear that working in groups was something students liked, however some students were still unprepared to work in assigned groups or with other students with whom they were unfamiliar. The issue with placing students in teams as opposed to letting students pick their own teams was also faced by other instructors of construction education. [8] indicate that forming groups based on students' traits might be a better arrangement for teamwork. Out of class meeting times were also a struggle for students, which is also something other researchers have found when combining assignments for different classes or universities [14]. Perhaps providing more scaffolding in how to work in teams and collaborate using technology can be helpful moving forward.

Also, the solutions presented by the students showed that they lacked understanding of the implications of the problem prior to developing solutions. Scaffolding students into the problem solving process, which includes understanding the problem prior to providing or searching for solutions [15], can help students work through real world, ill-structured problems. Students in the current construction management program are required to take a one-semester course in design thinking during which they discuss and apply problem solving strategies. However it is clear to the instructors that most students do not transfer the knowledge from that course to construction management problem solving situations.

VI. PARTIAL CONCLUSION AND RECOMMENDATIONS

Although more iterations of the assignment would be beneficial for strengthening the results, initial findings indicate that students do value working in teams and with real life problems. Most groups have provided input on the assignment and have clearly attempted to provide the best solution available. However, students did show a lack of understanding of the problem solving process, an indication, perhaps, that more scaffolding in problem framing and understanding could be beneficial. Also, due to the ever increasing importance of effective collaboration and communication, instructors still need to refine how to address team issues and to improve scaffolding students into working with teams that are not necessarily in the same class.

Based on the presented pilot experience, we have the following recommendations for cross-course integration of team assignments in the curriculum: (1) have clear goals, objectives and assessment methods for different classes; (2) provide students with more scaffold into teamwork with students attending different classes; (3) scaffold students into the problem solving process to make sure they understand the problem prior to looking for solutions; (4) if available, use real world examples of problems and then debrief students into the actual solution taken.

Both authors are currently working on applying the recommendations, as well as incorporating students' feedback into new cross course experiences for future courses. We recommend that these cross-course assignments be implemented and assessed over several semesters. Results from a systematic evaluation will allow instructors to make more informed adjustments to any future assignments.

Finally, despite covering a specific construction management assignment, the present experience can be helpful to other engineering and engineering technology educators who are looking for examples of active learning assignments and cross courses experiences. Other disciplines can use our findings to help identify topics for potential cross-course assignments, as well as help elaborate a work plan that includes scaffolding on problem framing and teamwork, a communication strategy (for students to communicate with instructors) and a thorough assignment debrief.

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