IMPLEMENTING A COLLABORATION ACTIVITY IN CONSTRUCTION ENGINEERING EDUCATION

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Abstract: Collaboration skills are increasingly necessary in today's construction workforce. However, classroom activities that incorporate collaboration skills, ones involving interactive work among individuals towards a common goal, are underrepresented in many construction classes. This research documents and illuminates implementation of a team activity where groups of interdisciplinary students were asked to build a structure using the provided (paper and tape) resources with the objectives to create a structure that stands at least 4" tall and supports as much weight (under textbook loading) as possible. Two rounds of activities were performed with differing levels of role definition provided to the students. Team interactions and performance were recorded, along with student self-assessments, and reporter observation. The implementation of this collaboration activity continues to provide valuable lessons, which informs the integration and assessment of collaboration activities in construction education.

1 INTRODUCTION

1.1 Collaboration in Construction Education

For purposes of this research, in the context of construction education, collaboration is the act of sharing or taking part in group decision-making processes concerned with equal participation and equitable power among a wide range of stakeholders from the owner and the professionals to the building users and representatives of the local community. Specifically, we adopt the definition of collaboration to be "an interactive process that engages two or more participants who work together to achieve outcomes they could not accomplish independently" (Salmons 2011). Collaborators should be prepared to listen to others, treat their ideas with respect and give one another equal decision-making power (Forsyth 2010). The goal of collaborative projects is to solve problems more effectively and produce better outcomes (Levi 2013). For instance, building delivery is not the result of one person's contributions; rather, it is the result of the technical collective knowledge from different disciplines. To make the process easier, information communication technologies and virtual models can be used to provide a better understanding of the visualization of designs, models and communication among participants (Emmitt and Ruikar 2013). In the context of this study, the most pertinent communication level is the group because of the amount of information required in designing and executing construction projects.

A number of publications highlight the importance of effective teamwork in the construction industry (Krug 1997, Levi 2013). For instance, partnering was developed to address conflicting objectives among owners, contractors, designers, vendors, suppliers, and government agencies, all of which also increased litigation among these parties (Gransberg et al. 1999, Anvuur et al. 2007). Researchers report that the primary benefits of partnering appear unlikely to be realized extensively unless cultural changes in the industry occur, specifically manifested in the development, communication, and pursuit of common goals

for projects (Dagenais 2007). The overall message is that design and construction activities need to move from a siloed to an integrated approach to improve performance and provide significant benefits for all project stakeholders.

Broadening the engineering and construction curricula by focusing on cooperative learning has been highlighted by several reform education agendas. Cooperative learning is based on the social interdependence theory that has been studied for more than five decades (Froyd et al. 2012), with the empirical and theoretical evidence supporting its efficacy (Felder et al. 1998, Springer et al. 1999, Prince 2004). In addition, more recent studies have begun to articulate the knowledge, skills, and habits of mind needed for students to perform satisfactorily in an interdependent world (NAE 2001 and 2005, Duderstadt 2009). Need exists to develop new evidence-based teaching strategies that can be implemented in construction and engineering programs to facilitate and change student skills in collaborative enterprises (Borrego and Henderson 2014). In the absence of acquisition of such skills, future professionals are likely to be less than optimally prepared to contribute to the building of future infrastructure.

1.2 Background

Previously, the authors published findings comparing pilot implementation of two interventions intended to increase collaboration among construction students: one paper-based and one computer-based (Valdes-Vasquez and Clevenger, 2015). High-level lessons learned included:

- Performance metrics for activity task performance should be integer-based to enable granular correlations about collaboration levels;
- In agreement with existing literature, diversity within teams appears to be correlated to the level of collaboration achieved;
- The learning environment (traditional paper-based versus computer-based) can impact the ability of teams to collaborate;
- Providing definition regarding individual roles and tasks during collaboration activities may or may not significantly impact team performance;
- Intra-experiment observation (a team reporter) is critical to studying collaborative activities.

2 RESEARCH OBJECTIVE AND METHOD

The objective of this research is to analyze an author developed in-class collaboration activity with distinct structured and unstructured implementations, analyze and compare results and evaluate potential impacts on students' collaboration skills as measured by metrics related to team performance and individual self-evaluation.

In this research, the authors chose to implement a paper-based collaboration activity with a group of students during fall 2014. Student participants were enrolled in an upper level course on sustainable design and construction. The course serves as an elective for upper level undergraduate and graduate students at the Colorado State University. Student enrollment consisted of twenty-seven students from construction management. The modified paper-based, as opposed to computer-based activity was selected for further implementation, due to ease of implementation since the selected objective of this follow-on study was to observe and analyze if structured (assigned) versus unstructured (unassigned) roles impacted team overall performance.

To perform the prescribed activity, facilitators provided the students with the following instructions:

Rules and Objective

Each group will build a structure with the materials provided the objective of which is to have the resulting structure stand and support as many textbooks as possible. Students may load the textbooks. The structure must hold the textbooks at least 4" off the ground plane for at least 10 seconds. The structure must be free standing and cannot be taped to the floor, ceiling, or any other structures.

First Round (Assigned Roles)

1. Each member of the group will receive specific resources (papers, poster boards, tape) and will only be able to use their own resources when building the structure.
2. One student will not receive any resources, but may help to lead the project.
3. The group will have only 10 minutes to build a structure.
4. After the 10 minutes, the structure will be tested.
5. The group with the more resistant structure will be the winner (see rules above).
6. Students will complete feedback form #2.

Second Round (No Assigned Roles)

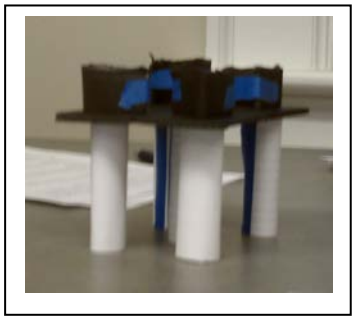
1. The group will be provided with a bag of collective resources (papers, poster boards, tape).
2. The group will have only 10 minutes to build a structure.
3. After the 10 minutes, the structure will be tested.
4. The group with the more resistant structure will be the winner (see rules above).
5. Students will complete feedback form #2.

During the two rounds of the collaborative activity the authors collected team performance data as well as qualitative student self-assessment data using intra-experiment observation. Specifically, during these contests one student in each team was assigned to be a non-participatory "team reporter" to record observations about team members' interactions. Finally, after each round of the collaboration activity, all student participants completed a survey, and results were analyzed. The questions for these surveys were adapted and synthesized from existing surveys regarding collaboration (including Borden & Perkins 1999, Kane & Harms 2005, Ohland et al. 2012).

3 COLLABORATION ACTIVITY IMPLEMENTATION

Five groups, each with four participants and one observer, completed both rounds of the collaboration activity. Figure 1 illustrates representative simple structures created by the student teams within ten minutes of receiving instructions. Figure 2 shows how students loaded these structures with textbooks to test their strength.

Sample A



Sample B

Figure 1: Sample structure created by the students

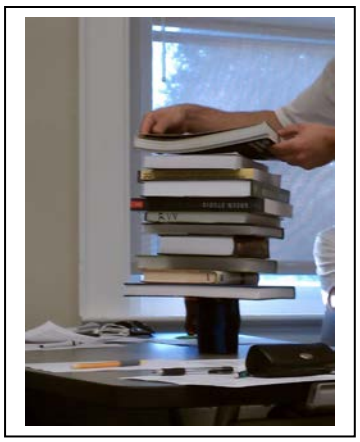


Figure 2: Student team loading the team's structure to test its strength.

3.1 Results

Three types of data were collected after each round of the collaboration activity: quantitative team performance (how many books could the structure hold), team reporter observations, and individual participants' self-reported qualitative assessments. The following three sections summarize these data.

3.1.1 Team Performance

Table 1 ranks team performance (according to total books supported across both rounds) as assessed by loading each structure with textbooks one at a time by the student teams. This simple measure was used as a proxy for team performance relative to the stated objective of the activity.

Table 1: Team Performance Ranked according to Demonstrated Strength of Structure under Loading

Team	Round 1 Structural Loading Achieved (No. of Books Supported)	Round 2 Structural Loading Achieved (No. of Books Supported)
1	4	11
2	5	9
3	10	1*
4	5	0**

* Structure Toppled while being loaded
**Structure Collapsed

While such a quantitative performance assessment metric (number of books) for the various teams was rather coarse, it proved interactive and informative. In fact, the authors noted that the act of loading the books on the structure, was, in itself, a potentially collaborative exercise- some teams involving numerous individuals as participants and coaches, while other teams chose to make the process individually oriented and independent. In future research, the authors hope to further study the collaboration that occurs at this stage of the exercise as well. Nevertheless, the "number of books supported" metric proved sufficient to rank team performance (see Table 1), and followed previous research findings that indicated that integer-based scoring, rather than binary (pass/fail) measures for such activities is useful for comparing collaboration achieved across teams.

3.1.2 Team Reporter Observations

The following are unordered lists summarizing comments noted by team reporters.

Team 1
- team did a good job of bouncing ideas around before they started to build
- ideas were extended to come up with a solution
- team used all of their resources
- everybody gave valuable input to come up with the final solution

Team 2
- members of the team worked well together and helped each other out during the construction of structure
- team thought through the design before beginning construction so there was less change in design while building
- good communication

Team 3
- open friendly atmosphere
- collective decision-making
- open to ideas from others
- group started working quickly

Team 4
- they collaborated a lot at the end to finish the project
- collaboration was evident when the time was running out also when a “break-through” was made
- poor communication vehicle for results
- made a plan and started early

Such results while illustrative, are not sufficient or sufficiently detailed to be informative. However, based on such comments and notes, the authors have determined that in future research, consisting of more rigorous assessment of student collaboration activities, trained researchers (as opposed to student peers) should be enlisted to act as third-party reporters in order to provide more consistent and informative documentation.

3.1.3 Individual Team Member Self-Assessment

After each round of collaboration activity, all student participants were asked to complete a survey where they responded to fourteen statements related to collaboration. These fourteen statements are presented around the radar charts in Figures 4 and 5. Specifically, after each round, students were asked to indicate the extent to which they “strongly disagree” (1) to “strongly agree” (9) with the statement based on their experience during the class exercise. Table 2 presents a summary of these results in numeric form, based on aggregated team averages.

Table 2: Team Averages for self-perceived levels of collaboration by Round.

Team (by performance level)	Round 1 (Assigned Roles)	Round 2 (No Assigned Roles)	Combined Average	Percent Change Between Rounds
1	8.21	8.43	8.32	+3%
2	7.64	7.98	7.81	+4%
3	7.36	7.51	7.44	+2%
4	6.72	7.24	6.98	+8%

Note for all teams, perceived levels of collaboration rose between round one and round two of the activity (see Table 2, Percent Change between Rounds).

Figure 3 and Figure 4 compare team averages according individual question responses related to self-perceive level of collaboration achieved for each of the four teams according to round 1 (Figure 3) and round 2 (Figure 4).

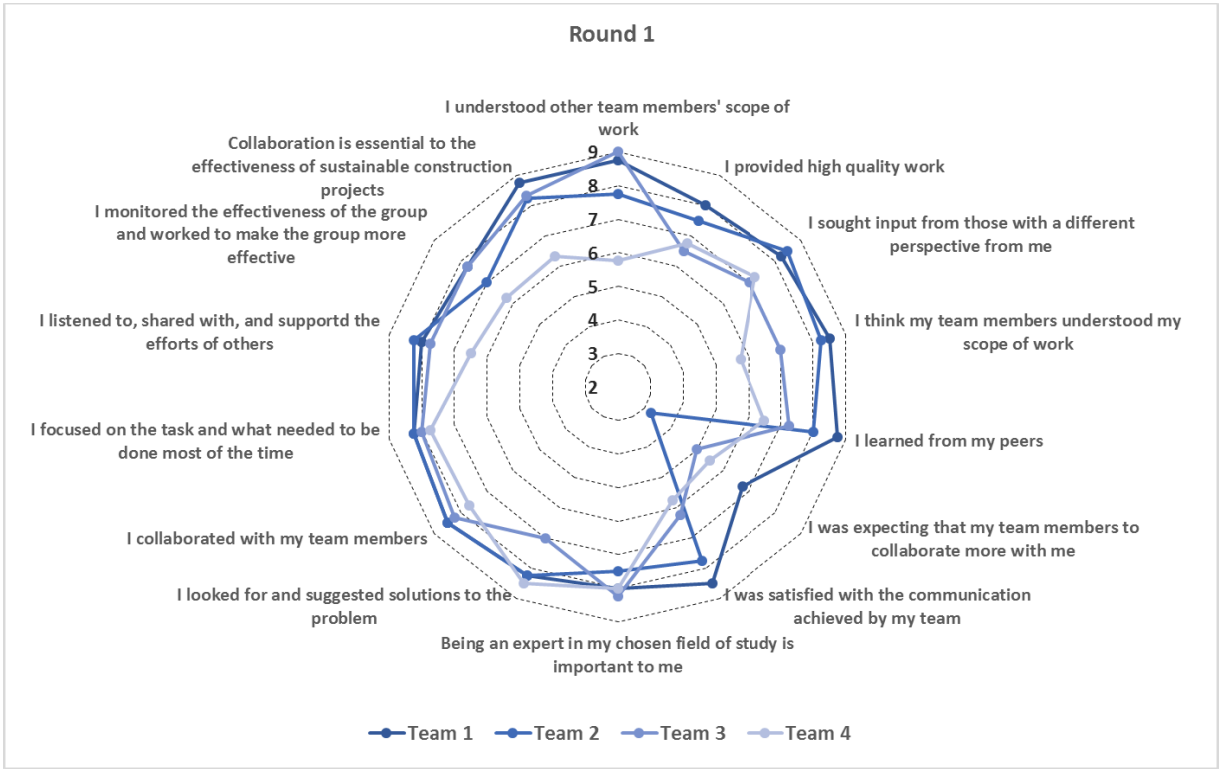


Figure 3: Round One (assigned roles) Self-assessment of Collaboration by Teams

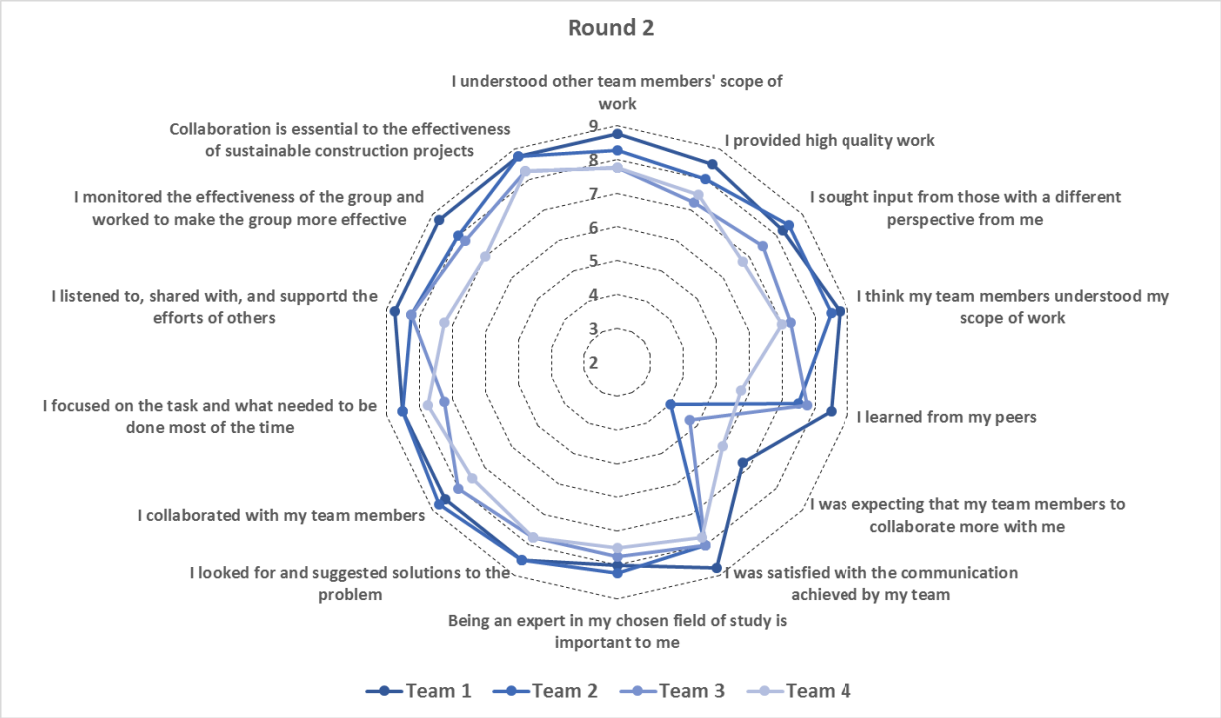


Figure 4: Round Two (no assigned roles) Self-assessment of Collaboration by Teams

Two observations are supported by the data presented in Figure 3 and Figure 4:

- Teams with higher performance generally reported higher levels of collaboration across both rounds of data collected.
- The biggest self-reported changes between rounds across teams occurred in relationship to the following statements:
  - I understood other team members' scope of work
  - I think my team members understood my scope of work
  - I was satisfied with the communication achieved by my team
  - Collaboration is essential to the effectiveness of sustainable construction projects

In each of these cases, the biggest changes in level of agreement (>14%) were reported by Team 4 (the worse performing team overall).

3.2 Conclusions and Future Research

Three preliminary findings are suggested by this research: 1) flexibility achieved through lack of assigned roles may improve collaboration level, 2) higher levels of collaboration may contribute to higher team performance, and 3) lack of understanding of the scope of work and poor communication may contribute to poor team performance. The authors acknowledge that significant limitations existed for this research including: the use of student peer team reporters; collection of self-reported data post (i.e., with prior knowledge of) team performance results; and possible transfer of inherent learning from one activity to the next which might impact (presumably improve) team performance. Nevertheless, the authors propose that the reported lessons learned serve as a valuable contribution with regard to implementing and assessing collaboration activities in construction engineering education.

Specifically, the authors make the following recommendations for further and future investigation:

- Impact of assigned individual roles on team dynamics and resulting collaboration levels achieved within the context of construction work-flows;
- Changes in team dynamics, and collaboration levels achieved between design and implementation phases of work;
- Relationship of levels of self-perceived collaboration to levels of collaboration reported by outside observers;
- Specific correlations (using statistical regressions) between specific self-reported levels of collaboration and overall team performance.

References

Anvuur, A., & Kumaraswamy, M. (2007). Conceptual Model of Partnering and Alliancing. *Journal of Construction Engineering and Management*, Volume 133, Issue 3, 225-234.

Borden, L. M., & Perkins, D. F. (1999). Assessing your collaboration: A self-evaluation tool. Journal of Extension, 37(2), 67-72.

Borrego, M., & Henderson, C. (2014). Increasing the Use of Evidence-Based Teaching in STEM Higher Education: A Comparison of Eight Change Strategies. Journal of Engineering Education, 103(2), 220-252.

Dagenais, D. A. (2007). Introduction to good faith in construction contracts. *Construction Management and Economics*, 25(7), 715-721.

Duderstadt, J. J. (2009). Engineering for a Changing Road, A Roadmap to the Future of Engineering Practice, Research, and Education.

Emmitt, S., & Ruikar, K. (2013). Collaborative Design Management. Routledge, Taylor and Francis Group.

Felder, R. M., Felder, G. N., & Dietz, E. J. (1998). A longitudinal study of engineering student performance and retention. V. Comparisons with traditionally-taught students. Journal of Engineering Education, 87(4), 469–480.

Forsyth, D. R. (2010). *Group dynamics.* Boston, MA: Cengage Learning.

Froyd, J. E., Wankat, P. C., & Smith, K. A. (2012). Five major shifts in 100 years of engineering education. Proceedings of the IEEE, 100(Special Centennial Issue), 1344-1360.

Gransberg D., Dillon, W., Reynolds, L., & Boyd, J. (1999). Quantitative Analysis of Partnered Project Performance. *Journal of Construction Engineering and Management*, 125(3), 161-166.

Kane, K., & Harms, J. (2005). Getting started: A guide to collaboration in the classroom. University of Hawaii at Manoa: The President's Educational Improvement Fund. Retrieved September, 1, 2013.

Krug, J. (1997). People skills: Teamwork. *Journal of Management in Engineering*, 13(2), 15-16.

Levi, D. (2013). Group dynamics for teams, SAGE Publications, Inc.

National Academy of Engineering (NAE) (2001) The Engineer of 2020: Visions of Engineering in the New Century, National Academies Press, http://books.nap.edu/openbook.php?record_id=10999&page=53, accessed Feb 15, 2015.

Ohland, M. W., Loughry, M. L., Woehr, D. J., Bullard, L. G., Felder, R. M., Finelli, C. J., ... & Schmucker, D. G. (2012). The comprehensive assessment of team member effectiveness: development of a behaviorally anchored rating scale for self-and peer evaluation. Academy of Management Learning & Education, 11(4), 609-630.

Prince, M. (2004). Does active learning work? A review of the research. Journal of Engineering Education, 93(3), 223–231.

Salmons, J. (2011) Taxonomy for Online Collaboration: Theory and Practice in E-Learning. Hershey: IGI Global.

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. Review of Educational Research, 69(1), 21–51.

Valdes-Vasquez, R., Clevenger, C.M., (2015), Piloting Collaborative Learning Activities in a Sustainable Construction Class, *Journal of Construction Education and Research*. 0.1080/15578771.2014.990122.