

Facilitating Teamwork Instruction in a First-Year Engineering Design Program: a Question of Balance

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Abstract - For over 15 years our first-year engineering design program has focused on a user-centered approach to design thinking and communication, where students work with real-world clients on ill-defined problems and communicate their ideas in a variety of ways to multiple audiences. To facilitate higher teamwork performance, we historically used two instruments to facilitate teamwork learning: (1) an intra-quarter peer review and self-review, and (2) an end-of-the-quarter reflective memo. In the fall of 2011, our program partnered with the university's Center for Leadership, to integrate opportunities for more teamwork reflection, peer- and self-assessment and teamwork improvement throughout the two quarter experience using an online interface. Peer-assessment and self-reflection pieces at the end of the quarter allow students to determine if they had been successful in achieving their mid-term goals. At the end of the year, however, when we surveyed ~425 students in the program, we were disappointed to learn that, while some of the students found the activities highly beneficial, an overwhelming number saw them simply as "busy work." In addition, a majority of the program's faculty were also frustrated by the new tools. Analysis of the survey responses and the teamwork activities suggested that the problem was one of balance: since teamwork is a goal of the program, but not its primary goal, we believe we built in too many exercises related to teamwork, ironically undermining their usefulness. In addition, by outsourcing the responsibility for administering the activities, faculty were less aware of when assignments were due, the roles of individual assignments, and how to readily assess and apply the students' responses. This study reports the problems we encountered in our attempt to improve teamwork instruction, presents our new hypothesis about how to teach teamwork in a first-year design course, describes the modifications we have made this past year and presents the areas of teamwork pedagogy that we are increasingly interested in systematically exploring.

Index Terms – Peer-assessment, Performance Goals, Self-reflection, Teamwork instruction

INTRODUCTION

Since its inception, the development of teamwork skills has been integrated into Design Thinking and Communication (DTC) at Northwestern University, a 2-quarter interdisciplinary course (DTC-1, DTC-2) required of all first-year engineering students. From the start, this took the form of supplementing the experiential learning that students gain in any team-based, user-centered design course with pedagogy specifically aimed at teamwork teaching and learning, including coaching by instructors, contemporary relevant readings, and lectures. Key concepts included the idea that (1) all teams develop through stages [1, 2], (2) successful teams work together toward a shared performance goal [2, 3], and (3) successful teams adopt a common approach and standards [2, 3]. The definition of a "true team," the foundation of our teaching, came from Katzenbach and Smith [4],

"... a small number of people with complementary skills who are committed to a common purpose, set of performance goals, and approach for which they hold themselves mutually accountable."

As the course evolved, students were expected to do more to connect the content from the readings and lectures with the experiences of the design project; they were required to complete five assignments: (1) two team process checks (members evaluate teams as a whole); (2) two team peer reviews (members evaluate each other's performance, including their own); and (3) a summative reflective memo focusing on teamwork experiences. These activities, taken largely from exercises used in business, were initially done in class, but eventually distributed and completed online with oversight provided by the instructors of record. Once the exercises were done online, they were used much more deliberately by section instructors, who previously often neglected the exercises because class time for the project work took priority.

Starting in the fall of 2011, the DTC program formed a partnership with the Center for Leadership at Northwestern University. The Leadership Center had created an extensive set of exercises for assessing individual and team

TABLE I
TEAMWORK ASSESSMENTS INTRODUCED INTO THE FALL 2011

Exercise	Emphasis/Focus	Time to Complete	Week Scheduled (out of 11)
Exercise 1: Write Team Charter	<ul style="list-style-type: none"> Examples of past team failures/ successes; identify positive & negative behaviors Discuss individual responses to step 1; identify positive & negative behaviors that the team should emulate/avoid Explore answers to the questions: Why do teams fail & succeed? How can a team maximize the likelihood of success and minimize failure? Write and submit the team charter 	90 minutes	Weeks 1 & 2
Exercise 2: Data collection from round 1	<ul style="list-style-type: none"> Individual comments on project and process; for each teammate and oneself identify one specific area for improvement; determine percent contribution of each teammate Comments on team performance; rating of team performance Ratings of instructors; comments on instructors' performances 	60 minutes	Week 4
Exercise 3: Identify improvements from round 1	<ul style="list-style-type: none"> Determine one improvement goal for each teammate Describe and list specific team improvements in detail Identify no more than three team changes Reflect on insights regarding individual and team performance 	60 minutes	Week 5
Exercise 4: Select personal goal for round 2	<ul style="list-style-type: none"> Describe what you heard from your teammates Describe what you selected as your personal goal Describe what suggestions you rejected and why 	30 minutes	Week 5
Exercise 5: Communicate personal goal for round 2	<ul style="list-style-type: none"> Each student discusses personal goal with team 	30 minutes	Week 6
Exercise 6: Data collection from round 2	<ul style="list-style-type: none"> Individual comments on project and process; for each teammate and oneself identify one specific area for improvement; determine percent contribution of each teammate Comments on team performance; rating of team performance Ratings of instructors; comments on instructors' performances 	60 minutes	Week 10
Exercise 7: Identify improvements from round 2	<ul style="list-style-type: none"> Determine one improvement goal for each teammate Describe and list specific team improvements in detail Identify no more than three team changes Reflect on insights regarding individual and team performance 	60 minutes	Week 11
Exercise 8: Select personal goal for working with future teams	<ul style="list-style-type: none"> Describe what you heard from your teammates Describe what you selected as your personal goal Describe what suggestions you rejected and why 	30 minutes	Week 11

performance during a quarter-long design challenge. These exercises were designed to monitor and promote growth for both the individual and the team in a more structured and systematic way than we had provided before. Through the assessments, teams had the opportunity to become more (a) aligned, (b) specific and (c) honest about each aspect of Katzenbach's definition as their work proceeds. DTC faculty

were strongly supportive of the collaboration with the Center because of their expertise in this area.

The assessments comprised eight exercises (see Table I) and were to be completed at strategic points during the quarter. They were originally piloted within two sections (out of 16) in the fall of 2011, using hard copies of the activities. Based upon instructor and student feedback, the assessments were moved online and piloted once again to a

subset of the 14 sections in the winter quarter. Based again on the feedback received from instructors and students, the online assessments were rolled out to all sections of DTC in the spring quarter of 2012.

To measure student opinions of the Center for Leadership online exercises, a formal survey instrument comprising five questions (see Methods) was sent to the first-year students. The results from this survey are presented here and motivated strategic changes to the teamwork exercises for the 2012-2013 academic year. These changes are described below, along with reflections on what went right, what went wrong, and why.

METHODS

A survey instrument (www.surveymonkey.com) was created and sent to ~425 first-year DTC students. Using a six-point Likert scale, students were asked to rate how helpful the online exercises from the Center for Leadership were in the following five areas (1 = not at all helpful, 6 = extremely helpful):

- 1) Helped me become a more effective team member
- 2) Helped to foster communication among team members
- 3) Helped our team to deal with conflict
- 4) Helped me to understand best practices for effective teamwork
- 5) Helped me to understand behaviors that can hinder effective teamwork

For each question the ratings were averaged and the median rating calculated. Students were also asked to explain their ratings for each question. For each explanation the content was coded as a positive critique (+), a negative critique (-), or a positive and negative critique (+/-). In addition, the responses were coded to form nominal categories. Synonymous terms were clustered and their counts summed. Frequencies of responses were then determined.

Based upon these responses, the DTC executive committee met with the director of the Center for Leadership to determine what went well with the assessments and what could be improved. As shown below, there was much room for improved delivery of the exercises.

RESULTS

Students were asked to rate on a six-point Likert scale their agreement with the five questions listed in the Methods section (n = 162). In addition, they were asked to explain their ratings.

Average and median ratings for each question are summarized in Table II, with values ranging from 1.64 ("helped our team to deal with conflict") to 2.09 ("helped me to understand behaviors that can hinder effective teamwork").

TABLE II

AVERAGE FEEDBACK ON LEADERSHIP CENTER ACTIVITIES

Question	Mean ^a ($\bar{X} \pm \sigma$)	Median
1) ... more effective team member	1.88 \pm 1.10	1.5
2) ... foster communication	2.03 \pm 1.23	2
3) ... deal with conflict	1.64 \pm 0.92	1
4) ... understand best practices	1.94 \pm 1.10	2
5) ... understand behaviors that hinder	2.09 \pm 1.20	2

^aBased on a six-point Likert scale with 1 = not all helpful, 6 = extremely helpful.

Student explanations were categorized as (+), (-), or (+/-). Of the 90 students providing feedback:

- 8 provided (+) comments;
- 52 provided (-) comments;
- 30 provided (+/-) comments.

For example, this comment—"it made me think about what made others good team members and what I could do to improve"—was categorized as (+). The comment "they felt more like busy work than actual learning experiences" was categorized as (-). The comment "while they do make you reflect, they are repetitive and frustrating to the point where their value is lost" was categorized as (+/-).

These responses were coded and clustered to determine factors that frequently influenced the ratings. Nominal categories were created based upon the specific words and phrases used by the students in their responses. As an example, the (+/-) comment above was counted in the categories (a) potentially beneficial ("make you reflect"), (b) repetitive/redundant ("repetitive"), (c) annoying/frustrating ("frustrating"), and (d) minimal learning ("value is lost"). Frequencies of (+) and (-) responses are shown in Tables III and IV.

Critically positive comments

TABLE III

CRITICALLY POSITIVE RESPONSES TO THE QUESTION, "THE ONLINE EXERCISES FROM THE CENTER ON LEADERSHIP HELPED ME TO BECOME A MORE EFFECTIVE TEAM MEMBER."

Clustered Responses	# of Responses (%) (n = 162)
Beneficial; potentially beneficial	35 (22%)
Promoted reflection	16 (10%)
Recognized weaknesses and areas for improvement (individually and within the team)	13 (8%)
Helpful for groups having problems	7 (4%)
Team charter was helpful	6 (4%)

Of the 38 students providing critically positive comments, 35 felt that the exercises were beneficial, or at least had the potential for being beneficial. Several students felt that the exercises helped them to reflect on their individual strengths and weaknesses. Others felt that they learned about best and worst practices for teamwork. Examples of positive student comments are listed below:

- It made me think about what made others good team members and what I could do to improve.
- It got me thinking about how I need to act.

- My teammates were able to tell me what I should improve on.
- They made us discuss and actually bring up flaws.
- They were helpful in the beginning when we were learning each other's strengths.
- It's more a "do it because it's on your grade" than because we want to. But sometimes they do help in identifying things that could go wrong.

Critically negative comments

TABLE IV

CRITICALLY NEGATIVE RESPONSES TO THE QUESTION, "THE ONLINE EXERCISES FROM THE CENTER ON LEADERSHIP HELPED ME TO BECOME A MORE EFFECTIVE TEAM MEMBER."

Clustered Responses	# of Responses (%) (n = 162)
Ineffective; No benefit; Minimal Learning	56 (35%)
Other approaches would be better	22 (14%)
Not relevant; Busy Work	21 (13%)
Tedious; a Nuisance; Annoying	20 (12%)
Repetitive	18 (11%)
Time consuming	8 (5%)
Students/Instructors did not take exercises seriously	6 (4%)

Of the 82 comments containing critically negative content, the primary concerns were about the lack of relevance and benefits of the leadership exercises to the team (see Table IV). Many students felt that the exercises were "busy work" and that most students (and a few faculty) did not take them seriously. In addition, many students felt that while the exercises in DTC-1 may have had value, revisiting them in DTC-2 was repetitive, tedious, and without value. Other students felt that the exercises could be improved, primarily by requiring fewer. Examples of student criticisms and suggestions for improvement include the following:

- A leadership lecture would have been better.
- [Exercises were] good for reflection, but too repetitive to retain value.
- Not helpful for a high achieving team [several students stated this].
- Team charter was helpful, but not much else [several students stated this].
- A single, mid-quarter evaluation of teammates would have been sufficient.
- Replace exercises with an active and candid teamwork conference w/professors or other advisers.
- [The] most (if not only) beneficial activity was where team members talked to each other about how they could improve [several students stated this].
- Allow team members to see what their team members wrote for each response.

It is important to note that teammates did not have access to their team members' critiques and suggestions for improvement except during a required team meeting in

which they discussed strengths and weaknesses of each team member with each other. The content shared in these meetings did not necessarily reflect the comments posted to the leadership site. Only DTC instructors had full access to the students' posted responses. This lack of transparency was intended to promote honest feedback from the students, without embarrassing them or putting them on the spot. In some cases, however, not being able to see what their teammates had posted online may have undermined trust among teammates.

What went wrong and why

The results above make it only too apparent that the vast majority of the students responding to the survey took issue with the educational value of the teamwork assessments.

Reflecting on the experience of introducing these teamwork exercises into the 2011-2012 DTC curriculum, the faculty recognized that their implementation was flawed in several ways.

- 1) *DTC faculty were not sufficiently familiar with the structure of the teamwork activities, when each was due, and how they related to the course.* This was an ironic unintended consequence of our effort to relieve faculty from at least one of their many responsibilities in this complicated course. By automating the teamwork assessment so completely and relying on the Center for Leadership to communicate teamwork content and exercises to the students, faculty became too removed from this element of the course. They were confused about when the assessments were due, whether they were supposed to emphasize teamwork in class meetings, who was responsible for assessing the exercises, and who was responsible for holding the students accountable to complete the exercises in a meaningful and timely way.
- 2) *The DTC syllabus did not provide enough guidance on the teamwork exercises for the students or the instructors.* The syllabus is the guiding document for DTC. With 14+ sections each Fall/Winter quarter, and 24+ sections in the spring quarter, both faculty and students rely upon the syllabus to ensure that lessons and expectations are relatively uniform across a program employing 30+ instructors and enrolling 400+ students. The Fall 2011 and Spring 2012 syllabi showed when the teamwork assignments were due, but did not explicitly encourage faculty to discuss the teamwork assessments, their relevance to the course or the students' responses to the assessments. This was in contrast to the handling of other assignments related to the design process, for example, the importance of sketching to communicate and understand ideas, the use of statistics in performance testing, or expectations for written deliverables, such as progress reports or individual essays. All of these are explicitly listed in the faculty version of the syllabus as topics to emphasize in

TABLE V
TEAMWORK ASSESSMENTS INTRODUCED INTO THE FALL 2012 SECTIONS OF DTC

Activity	Emphasis/Focus	Time to Complete	Week Scheduled (out of eleven)
Draft of Team Charter	<ul style="list-style-type: none"> Creates guidelines and standards for students to follow; establishes a foundation for high-performance teams. 	120 minutes	Week 2
Final Version of Team Charter	<ul style="list-style-type: none"> Integrates faculty feedback into above document 	30-60 minutes	Week 3
Mid-quarter review	Team members: <ul style="list-style-type: none"> Document individual contributions to the project as well as to the process; Evaluate team performance; Collaborate to develop performance goals for each team member; Collaborate to determine up to three changes to their; teams standards or performance goals. 	90 minutes	Weeks 4 & 5
End-of-the-quarter review	Team members: <ul style="list-style-type: none"> Receive feedback from classmates on individual performance, including progress made on the development goal established during the middle of the quarter; Select one area for improvement next time they are on a team; Identify three habits that promote effective teamwork; Draft a memorandum that describes insights about individual and team performance, specifically as these relate to the team's charter drafted at the beginning of the quarter. 	135 minutes	Weeks 10 & 11

class. This lack of in-class discussion may have caused students to underestimate the importance of the assessments. In addition, the syllabi did not list expected learning outcomes for teamwork as it did for design process, graphics, and communication. These oversights may have caused the students to question the relevance of the teamwork activities to their design project, in turn, leading them to label the exercises as “busy work” (a term they use all too readily for many of the assignments in DTC, even those that they come to value later in their undergraduate career). The syllabus also did not explicitly list how the teamwork assignments would be weighted in the final course grade. While they were included as part of the student’s “individual grade,” this only comprised 10% of the final grade, of which, the teamwork assessments were only a small part.

- 3) *Adding eight additional exercises to an already crowded curriculum was a mistake.* The principal strength of the DTC curriculum is that students experience the importance of effective communication to the engineering design process as well as how each discipline relies so heavily on “iterating to excellence.” The course is co-taught by engineering and communication faculty, each with their own educational goals, which results in a heavy load of assignments for the students. High achieving teams spend 12-15 hours per student each week meeting the design and communication requirements of the course. One might think that ways to help students communicate effectively and work more productively in teams might

actually decrease their workload. However, for the great majority of

students, these exercises were simply an increase in the workload which they never understood.

- 4) *Delivery of the assessment was flawed.* Close inspection of Table I shows that teamwork assignments were due in weeks 1, 2, 4, 5, 6, 10 and 11. While the parsing of the exercises was purposefully done to avoid any individual exercise from being too time-consuming, this approach made it difficult for instructors and students to stay on top of due dates as well as the connections between the assignments. While each exercise was accompanied by an email from the Center to the student stating when the assessment was due, emails were not sent with the same frequency to the instructors. This led to miscommunication between the students and the instructors. In cases where activities were not accomplished on time, the Center sent follow-up emails. By the end of the quarter the number of emails sent from the Center for Leadership to the DTC students was overwhelming.

These problems were apparent to faculty as well as students. In an end-of-the-quarter meeting, faculty were vocal about their discontent and suggested many possible improvements.

What went right

Much has been written about the power of reflection in promoting retention of learned material. The Center for Leadership exercises require students to reflect on four key

aspects of teamwork: (1) the team's charter (or shared standards); (2) their individual performance; (3) their teammates' performances; (4) the performance of the team as a whole (see Table V). In response to these reflections several benefits occur, including the frequent referencing of the team's requirements for measuring effective teamwork, identification of effective and ineffective teamwork practices, setting of goals for the individual student and the team, and documenting progress toward meeting these goals.

Our goal would be for all students to recognize these benefits, and this obviously didn't happen. However, a quarter of the students (38 out of 162) did see these benefits and were able to clearly articulate at least a subset of them. This suggests that more students could be reached if we improve the pedagogy.

What we are working to correct

In planning for the 2012-2013 AY, faculty's main concern was how to work with the Center for Leadership to streamline the teamwork exercises. Inspection of the exercises from 2011-2012 showed that they cluster into three principal activities: (1) the forming of a team charter which comprises a mission statement, performance standards, and team goals; (2) a mid-term review of individual and team performance as well as establishing goals for improvement for both the teammates and the team as a whole; (3) an end-of-the-quarter review (see Table V).

In 2012-2013, we used these categories to reduce the number of emails students would receive from the Center and increase faculty involvement with the lessons. For example, we decided to have faculty introduce the front end activities—the team charter with performance standards and teamwork goals in class. Once students posted their charter on the Center's website, they did not receive any emails from the Center until week four, and then not again until the end of the quarter, week ten. This was in marked contrast to the previous year's activities which had been sent out on a weekly basis. While the two 2012-2013 individual assessments required nearly two hours from each student, the connections between the activities and their timing were planned to be more logical to students and faculty – as a mid-quarter and end-of-course reflection. In addition, we made changes to the textbook and had more discussion about the teamwork exercises in our weekly faculty meetings.

Reflecting on how to strike the right balance between involving the DTC faculty in the teamwork instruction while outsourcing some of the instruction to the Center on Leadership and working collaboratively with the Center, we realized with some surprise that we had neglected one of the pedagogical pillars of our class that we may have taken for granted: that of making the course sufficiently "community-centered."

In a 2004 presentation on teamwork to the Association for Business Communication by P. Hirsch et al., the "How People Learn (HPL)" framework [8] was used to describe how teamwork was delivered in DTC at that time. This

framework stresses the importance of four dimensions for successful learning: a learning environment should be knowledge-centered, learner-centered, assessment-centered, and community-centered. DTC has always been community-centered in several ways: by having the students work on community-centered projects; by having the students meet several times in the quarter as a large group, as in the weekly lectures and their end-of-the-quarter project fair; and by having an interdisciplinary faculty from two schools (Engineering and Arts and Sciences) meet weekly as a learning community to plan curriculum, share teaching strategies, discuss problems, etc. Community-centered environments promote collaborative learning, i.e., students and faculty learning together and from each other, new and experienced faculty learning together and from each other. Ironically, in our 2011-2012 teamwork instruction, while a lot of learning was taking place between the director of the Center for Leadership and the executive committee for DTC, much of this information was not being effectively communicated to the other DTC faculty or, in turn, the DTC students, and thus was also not benefiting from their insights.

In reflecting on last year's activities and modifying our teamwork pedagogy, we have worked more collaboratively, thereby strengthening the community. However, we suspect that we need to do more in this area: faculty still need to be more involved in the new program and need better guidance as how best to use the Center's activities effectively.

The importance of a community-centered learning environment cannot be overemphasized. Analysis of the 2011-2012 data provided by the students shows ample opportunities for pedagogical improvements, probably more than we have implemented successfully in one year. Our teamwork instruction, now integrated with the Center for Leadership, continues to be a work in progress as it takes time for a community to come together.

CONCLUSIONS AND FUTURE WORK

At this time, feedback from DTC faculty about the Center for Leadership assessments has not been formalized. Any comments about the Center's teamwork activities have been given at DTC faculty meetings or during *ad hoc* discussions. Going forward, a survey similar to the one sent to the students will be created and sent to the DTC faculty. In addition, a structured focus group will be organized in which faculty form teams to discuss the strengths, weaknesses and opportunities for improvement for each leadership exercise, drawing on a format that one of the authors has used to capture feedback about a program he directs.

Critical insights discovered during this analysis are (1) the importance of faculty buy-in to the success of new pedagogical tools, particularly when those tools utilize new technologies, (2) the importance of helping students see the relevance of everything we teach, especially in an exciting but stressful project-oriented freshman design class, and (3) the necessity to continue to search for the best ways to teach

teamwork in design. By continuing to streamline the teamwork activities in our class and make faculty more responsible for integrating those activities into each section, we have made a good start. But, as DTC faculty and the Center for Leadership, we need to continue to iterate our own design to achieve a teamwork teaching and learning delivery system that satisfies the needs of all stakeholders involved with DTC.

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