

Enhancing Cross-disciplinary Collaboration and Innovation for Engineering and Business Student Teams

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A cross-disciplinary team was formed to compete in the Department of Energy Collegiate Wind Competition 2016 (CWC). Requirements of the CWC are to conceive of and develop a viable business with a marketable product that uses wind as its sole power source and develop a prototype wind turbine and load system. Competition judges evaluate a written business plan, public and private business plan and deployment strategy presentations, and wind tunnel testing of the prototype wind machine. Given the cross-disciplinary requirements of the CWC, a team was formed through a collaboration between faculty in the colleges of business and engineering. A team of students from a business social entrepreneurship course formed the core business group while a senior capstone team was formed to manage the technical challenges. Given that these groups do not normally work together in an academic setting, workshops were developed by the two faculty co-advisers and delivered throughout the semester with the objectives of providing students with just-in-time information and support to help manage and deliver on the competition requirements. This paper describes the workshops that were designed and implemented, student feedback on pre- and post-questionnaires, and what worked and what needs improvement for forming and advising cross-disciplinary teams in the future.

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Introduction

Assistant professors in mechanical engineering and business management-entrepreneurship wrote the proposal that was accepted by the Department of Energy (DOE) to compete in the biennial CWC. Objectives of the proposal were to foster cross-disciplinary collaboration on campus, grow a culture of entrepreneurship, and raise awareness and provide learning opportunities for the growing wind energy industry. These objectives aligned well with the strategic plans of the university, colleges and DOE.

The CWC is a technical design and business plan competition for undergraduate students. The competition requirements are to design, build and test a prototype wind turbine, create a market-driven business plan, and develop a deployment strategy. Initially, the team was formed with students from engineering and business majors. Engineering students were assigned to the CWC team through their senior capstone design course and consisted of two mechanical engineering and three mechatronic engineering majors. The business group formed from five students enrolled in a business social entrepreneurship course. As the semester progressed, several additional students joined the team mainly from majors in mechanical and civil engineering and business marketing and entrepreneurship. A total of twelve students participated regularly during the fall 2015 semester.

The CWC team has no customer, *per se*, nor readily identifiable performance specifications. This creates a challenging environment for students because they have to drive all the requirements and assess feasibility. Additionally, students must develop engineering specifications and validation tests, and the application must be based on a market need and be financially feasible as a business. These challenges require students to be independent confident decision makers and critical evaluators of multiple ideas across disciplines, something they are not accustomed being. However, these are valued characteristics of many programs as well as ABET^{1,2,3,4,5}.

There are many engineering programs that focus on multi-disciplinary engineering projects and many that include industry sponsors⁶. These academic programs provide students with valuable project based-learning experiences with opportunities to interface with industry in a safe environment focused on learning and development. However, most of these programs are fundamentally engineering projects requiring solely engineering solutions. Additionally, while a solution may not exist *a priori* project sponsors generally provide adequate constraints and feedback that help guide engineering students toward viable solutions.

Recognizing these significant challenges and because membership in the CWC was voluntary, a just-in-time approach was adopted for delivering content to students

in the form of workshops focused on the immediate needs of the team. This model was selected to more closely represent the dynamic environment of a new business technology startup and to avoid creating an environment where assignments are given and deadlines are established and driven by an instructor.

Team Values, Mission Statement, and Contract

One of the first workshops focused on creating core team values and developing a mission statement. The team was briefed on the importance of creating core values and how the overall values of the team result in the collective understanding of the mission and create a sense of belonging, leading to a stronger commitment. Individuals were given a list of over fifty words representing values such as ambition, kindness, integrity, etc. Students picked five words and/or added their own words and ranked words in order of personal preference. All words were combined into one list and ranked based on the frequency of a selected word. Some words were combined into one if the team felt that one word could adequately represent multiple words. This continued until the team had a list of five words that best represented the core values of the team.

A mission statement was created from the five words and was followed by a team contract. The team was provided with a template for a contract adapted from Trevisan, et al². Elements of the team contract included roles and responsibilities, team relationships, team meetings, individual expectations, documentation and communication protocol, and conflict resolution. The contract was completed and circulated among all members, and when approved, it was signed and became the governing document for the team.

Positive Team Characteristics and Behaviors

A workshop on teamwork and how to contribute to a high achieving team was delivered with content adapted from the instructors' experiences as well as Pellerin⁹ and Trevisan, et al². Key elements included describing and understanding the motivations for why individuals work on teams and what the underlying needs of the individual are in working on a team and how to nurture and support those needs to maintain a positive, constructive, and successful team environment. These characteristics were presented and discussed with the students and used as a self-assessment tool⁹ to evaluate each individual's contribution to the team and to identify areas that need to be addressed or supported for process improvement.

New Product Concept Development

A new product development workshop was designed to help focus on the essential information needed to assess product ideas. A concept disclosure template was provided that is commonly used in industry to evaluate

product ideas. The template is a relatively simple document that identifies key areas of understanding including a picture/image, problem definition, how the product solves a problem, description of the customer, description of the market, competition, competitive advantage, intellectual property or unique technology, and how the product makes money. Students worked together to evaluate and current product idea and shared their results as a team.

Self and Team Assessments for Improvement

Eight behaviors were described and integrated into a self and team assessment. The importance of maintaining these eight behaviors was discussed and scenarios of when teams failed to address these behaviors was presented. Using a self and team assessment as a tool to monitor team dynamics and effect change was also discussed. The assessment was used at the beginning, middle and end of the semester and discussed with the team.

Sharing Activities

Several presentations were prepared by the students and given to the students. Engineering students prepared and presented the key performance and design considerations for developing wind driven power systems. Similarly, business students presented the fundamental elements of a business plan, market research, and understanding the customer perspective.

Additionally, engineering students participated in several events that were held during the social entrepreneurship class. As teams of business students were conducting market research, reaching out to potential customers, and investigating market leads and contacts, engineering students visited their class as technical experts and collaborated on the technical aspects of the market driven concepts. Approximately, two one-hour sessions were dedicated to having one engineering student per market research team collaborate, discuss, and identify technical issues that related to the various market opportunities being investigated.

Assessments

Two questionnaires were given to the students, one at the beginning of the semester and one at the end. Both questionnaires included mostly Likert-scale questions with space comments. The pre-semester questionnaire focused mainly on teamwork experiences and attitudes and included the following questions.

1. Have you worked on an academic team?
2. Do you like working on a team?
3. If assigned to a team project, how would you feel?
4. Have you ever been trained to work on a team?

5. Is it necessary to work on a team?
6. Are you well prepared to work on a team?

The second questionnaire was administered at the end of the semester and included the following questions plus several open ended summative questions. The questions with Likert scale responses follow.

1. Have you worked on a team with students from a different college?
2. Considering the CWC experience, do you like working on a cross-disciplinary team?
3. If assigned to a team project, how would you feel?
4. Do you think you were well prepared at the beginning of the semester to work on a team?
5. Do you think you are now better prepared to work on a team?
6. Compared to projects with students in your major, what did you think of working with students from a different college?

The summative questions queried students for what they liked, what needs improving, and what recommendations they have to make the stated improvement.

Results

A total of ten responses were collected for the first questionnaire and seven for the second. Responses to the pre-questionnaire were as follows.

- Q1: 10-yes, 0-no
 Q2: 1-not really, 5-neutral, 3-like to, 1-love to
 Q3: 1-dread it, 3-neutral, 6-excited
 Q4: 7-yes, 3-no
 Q5: 10-yes, 0-no
 Q6: 3-probably, 7-absolutely

The post-questionnaire answers follow.

- Q1: 1-yes, 6-no
 Q2: 1-no, 1-neutral, 4-like to, 1-love to
 Q3: 1-dread it, 1-neutral, 5-excited
 Q4: 1-easy, 2-same, 4-hard
 Q5: 2-I don't know, 2-probably, 3-absolutely
 Q6: 1-easy, 2-same, 4-hard

Qualitatively, the students socialized well. Meetings started on time, though often lasted longer than they were scheduled and were well attended. Everyone was respectful and engaged.

During the workshops, students seemed to participate with enthusiasm and interest. During the team values workshop, students actively discussed various values and definitions and collaboratively developed their list of guiding principles. Likewise during the workshop on self-assessments and behavioral characteristics, the students were engaged and interested. The business professor led a discussion on the importance of

appropriate and adequate market research and the value of listening to the customer. This was a particularly rousing workshop in which the students participated and were highly engaged. The workshops seemed to provide adequate information for students to engage in collaborative activities such as market research, developing a team contract, and ideation.

Team performance and individual contributions were lower than expected. The team missed all internal deadlines, meetings lasted longer than planned and often without resolution on issues, and there was a lot of confusion with roles and responsibilities.

Discussion

After careful consideration and reflection on the past semester, there are a few key issues that resulted in mixed performance. Students seemed to desire to work together and embrace a multi-disciplinary project, however there was a lack of understanding about how to work as a team, communicate, and set clear roles and responsibilities. Additionally, the competition required students to conceive of an innovation or application that did not exist, decide whether the idea had merit and design both a market analysis and business plan as well as a prototype to justify their concept. These are challenging tasks and highly open ended for which the students did not seem well prepared.

Six out of ten students from the pre-questionnaire and five out of seven students in the post-questionnaire answered that they would be excited about the opportunity to work on a team. This equates to about 65% of all students excited about working in a team environment, which seems consistent with a team of volunteers. Seventy percent of students in the pre-questionnaire, i.e. at the start of the project, believed they were absolutely well prepared to work on a team. This changed in the post-questionnaire to only 28%.

Of the students that indicated that they were excited to work on a team in the pre-questionnaire, 100% felt that they were *absolutely* well prepared for teamwork. Whereas in the post-questionnaire, four out of seven respondents (57%) indicated that they thought it was hard or really hard to work on a team with students from a different college. These results seem to indicate that several students started the project with high expectations of themselves and perhaps overconfident about working in a multi-disciplinary team. These results are also reflected in the following observations.

Students within sub-teams often waited on other sub-teams before pursuing ideas, designs, or research. Business students waited for engineers to decide what the design was going to be and engineers waited for business students to decide the market and product. Multiple times during team meetings, one or the other group would directly say that they were waiting on the other group

before they could get started. Faculty encouraged groups and individuals on various occasions to research markets and technologies from a broad perspective in order to narrow down the possibilities or research the competition for ideas or reach out to industries and inquire about problems or struggles with energy and power, but there was a significant reluctance to move forward with research to evaluate whether or not a given idea had merit. Both engineering and business student alike seemed to struggle with moving a concept forward.

Neither group focused well on what was unknown about an issue nor endeavor to find answers. Rather, teams focused on finding a discrete data point to use to drive decisions. As a result, decisions were made based on only partial information. It appeared that the students were trying to find something concrete on which they could base a decision, and the act of making a decision was more important than the quality of the decision.

Based on the past semester's performance and quality of student deliverables the following changes will be made in future implementations. More time will be spent understanding the new product development life-cycle from the perspective of production as well as business strategy and management and examples of successful and unsuccessful product launches will be provided. More consistent and continual support will be given to student leads on how to manage teams. Finally, there will be a focus on the overall team as the entity that drives decisions and deadlines as opposed to supporting courses in which the students are enrolled.

Another change that will be implemented in the future will be to advertise campus wide for CWC student members at the beginning of the competition semester and let the students self-govern from the beginning. The CWC proposal was awarded in the spring semester and since both faculty members who submitted the proposal were new to the University, they had to appoint students from their courses to be the first members. While these students were extremely helpful in getting the CWC off the ground, because they were selected by faculty they looked to the faculty for direction and decisions as opposed to taking initiatives themselves. Additionally, when the CWC team grew, it grew because of students being assigned to the project from either course, social entrepreneurship or engineering, which shifted the motivation of the students to be primarily based on course responsibilities and requirements and not based on the team's organization and direction.

An additional change was implemented at the start of the spring semester. Students were required to sign a contract in which they committed to working at least 10 hours per week and volunteering for one or more administrative positions as part of their requirements for traveling to New Orleans, LA for the competition. The hour requirement included time spent on assignments for both business and engineering courses related to CWC

outcomes. This contract was intended to establish clear expectations of all team members.

While conclusions are thus far based on observations, insight, and limited student feedback, it seemed that working with the ambiguity of an unknown market and product was a major challenge. Focusing on how to effectively prepare students to cope with this type of environment could make a significant impact.

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