Improving Engineering Students Professional Development Skills in the Make to Innovate Program

Matthew E. Nelson
Department of Aerospace Engineering
Iowa State University
Ames, Iowa, USA
mnelson@iastate.edu

Benjamin Ahn
Department of Aerospace Engineering
Iowa State University
Ames, Iowa, USA
bahn@iastate.edu

***Abstract*—A program at Iowa State University, Make to Innovate (M:2:I), allows students to work on real world engineering problems through a problem-based learning framework. Over the five years this program has been operating, observational data and student feedback have been collected identifying a potential issue with students' success in their projects. In most cases, this was not due to a lack of technical knowledge but rather from deficiencies in professional development skills. However, students are not often exposed to or taught these professional development skills in their undergraduate courses. This creates a deficiency in students' effective leadership of their teams, which can lead to a negative experience for the student in the program.**

This work-in-progress paper will discuss a supplemental professional development course that will be added to the Make to Innovate program to educate students in several professional development skills. This additional instructional course will continue to follow the problem-based learning framework to engage students in learning these skills. The developed course is expected to have direct positive impact on students' professional development and the success of their projects.

Keywords—professional skills, teamwork, leadership, ethics, communication, undergraduate, Multidisciplinary design

I. Introduction

Professional development skills are skills that many have indicated are lacking in the education of many undergraduates [1]. Students are expected to graduate with knowledge in leadership, communications, teamwork, and other professional skills. According to Siller, Asce, Rosales, Haines, and Benally [2], "the development of engineering students' professional skills has gained national attention from the Accreditation Board for Engineering and Technology, the National Academy of Engineering, ASCE, and other constituents" (p. 109). The inclusion of these professional skills in turn aids students to achieve more with the technical skills they already have [3].

Engineering students are now expected to have these professional skills, which add value to the companies that will hire these students. Over the years, changes in technology, globalization, and how companies hire have placed a greater emphasis on professional skills [4]. This has caused greater competition among students entering the workforce and requires students to have additional skills beyond the engineering skills learned in the classroom.

However, professional skills are often not taught to engineering students in a direct method. Instead, it is expected that students acquire these skills indirectly through group projects in their courses. But students often struggle in these environments, and because the skills are not taught directly to the students, they are neither sure how to correctly implement these skills nor do they have a clear understanding of those skills. For these reasons, we have seen professional development skill courses developed and offered to engineering students to improve these skills (for example [5] and [6]).

In this paper, we will examine a supplemental course that was piloted to students that are in the Make to Innovate program at Iowa State University. This paper will introduce the Make to Innovate program and then discuss the professional development skills that were taught. In each category of skill, we will outline the learning objective, the activities and in class discussion, and finally the feedback and lessons learned from the skills taught in the pilot program. We will then conclude this paper with a discussion of the future work for this program, including a digital badge program designed to examine students' development of these professional skills.

II. Make to Innovate Program

The Make to Innovate program is a program run through the Aerospace Engineering Department at Iowa State University. Although it is run and managed by the Aerospace Engineering department, it is open to all students at Iowa State University including those outside the College of Engineering [7]. This allows students to interact not only with a variety of projects but also with a variety of students. The program is open to all undergraduate students--freshman through seniors.

The program, at the time of this paper, has thirteen different engineering projects. This includes an underwater vehicle, an autonomous sailboat, a Mars Rover, several Unmanned Aerial Systems (UAS), our High Altitude Balloon (HAB) project, and finally our Cubesat project. Nearly all projects are multidisciplinary projects that incorporate Aerospace, Electrical and Computer, Mechanical, and Chemical engineering. Many of the projects also need students from Meteorology, Biology, Computer Science, and Business majors.

For this pilot study, only the project leaders were selected to be in the supplemental course. In order to be a project leader,

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students must be a Junior or Senior and enrolled in the AerE 494X course for three credits. Within each project there are two to five teams, and each team has a team leader. This creates a hierarchical system where the project leader oversees the big picture of the project and thus directs the team leaders. The team leaders then oversee the students in their respective team.

III. Theoretical Perspective

The framework or lens for this research is based on the Problem Based Learning (PBL) framework. The PBL framework is student centric, uses small student groups for learning, and the instructor is present to provide guidance [8][9]. This pedagogical approach has students learning in collaborative groups and is focused on student engagement in the learning process [10]. In order to facilitate this, PBL anchors the learning in a stated problem, the students then collaboratively work together to solve the problem, and through that process learn from each other. The instructor is secondary to the learning process and is there more to guide the students, but the emphasis is on the students learning from each other as they solve the problem.

The use of PBL in engineering courses is not new and has been implemented in a number of courses to allow students to grasp engineering concepts and reinforce what the students have learned [11]. Courses at Iowa State University also have used the PBL framework including the Make to Innovate program. The use of PBL to teach engineering students professional development skills is also not a new concept. Some examples include engineering ethics courses [12], teamwork and communication [13], and even a course designed to improve students' overall professional development skills [10].

Since the Make to Innovate program and other engineering courses use the PBL framework, this framework was continued to teach the professional development skills for the course outlined in this paper. The activities used were developed with a student centric approach, and students were to get into groups to solve the problem. Students were given a problem in their respective groups and then worked on the solution. As with the PBL framework, the instructor was there to offer guidance, but the intention was that the students work on the solution on their own.

IV. Professional Development Skills

For this research, we focused on five professional development skills taught to undergraduate engineering students. These skills were selected based on skills that were identified to be either weak or missing in the students current curriculum at Iowa State University and were found to be important for engineering undergraduate student to possess [14] . The five professional development skills are: Teamwork, Communications, Leadership, Diversity, and Ethics. A minimum of two weeks, each week having about two hours of contact time with the students, was spent on each skill. Activities were used to enhance the student learning of these skills. We piloted this course to engineering students that were project leaders in the Make to Innovate program. There were thirteen projects, so thirteen student leaders participated in the course.

Because this is a work in progress paper, three of the five skills will be discussed in detail as those skills have been covered in the course. These skills are teamwork, leadership, and communication. Ethics is being covered even as we write this paper, with diversity finishing the semester for this course. The following section will examine in greater detail each professional skill that was taught, what activities were used, and what we learned through the process to improve the course in future iterations.

A. Teamwork

Teamwork is a skill that teaches students how to work in a team environment. This includes areas such as resolving conflicts, organizing a team, team behavior, and what contributes to making a good team. The differences between teams that are effective and teams that have lower productivity are also discussed and compared.

1) Learning Objectives: The learning objective for this skill is to introduce students to the basics of what makes a good team. This includes characteristics of a good team, some mistakes common to a team environment, team performance-building, and proper team support. Students are also given tools such as creating a code of co-operation and tips on handling conflict within teams.

2) Activities: For teamwork, in-class activities made the students think about how teams should be organized and how to approach and resolve conflicts within a team. Discussion points included the following questions that were posed to students.

- What was your experience working in your project?
- How did your team structure compare to the team structures we discussed?
- Why do you think teamwork is (or is not) important in engineering?
- What teamwork attributes do you see in your team?
- What might you do differently in organizing your team?
- How well do you think your team functions?
- What can you do to improve your team?
- What rules (if any) do you have for your team?
- What activities (if any) do you do in your team?
- How do you track your team's progress?
- How do you challenge your team?

Two pen and paper exercises and one electronic game exercise were used as activities during the sessions. These allowed for an interactive method for the students to discuss the talking points we outlined in this section. For all exercises students were divided into groups of four or five students. The first pen and paper exercise asked each student group to come up with three keywords they felt best represented their project. These were then collected and mixed up and then given to a different group. Those groups then had to agree as a group, which project the three keywords represented.

The second activity had the groups come up with their own code of conduct for their group. As a starting point, the code of

conduct was discussed in class and examples were given to the students. After the groups had determined their codes of conduct, we discussed some of the differences between each group's code of conduct and rationales for their choices.

The final activity used an electronic mobile game called "SpaceTeam" created by Henry Smith [15]. This activity used iPads running iOS with the mobile game on it. In the game, students must communicate to other teammates what button they should push on their hand-held device. The fast nature of the game, however, often pushes the envelope on how well people communicate in high stress environments. To get far in the game, students must adapt strategies for how they communicate and how they work as a team.

B. Communications

Communication is a skill often taken for granted. Many students confuse communication with effective communication. For this section of the course we focused on effective communication--both oral and written.

1) Learning Objectives: The learning objectives are to introduce to the students both written and oral communication skills as they will be needed not only after graduation but also throughout the students' academic career. For example, the students in the Make to Innovate program need to present at a design review in front of the advisors and peers and must submit weekly and milestone reports. Students were introduced to what makes good oral presentations and why this is important. An example of this is the students are expected to present their work in Make to Innovate at a mid-term design review.

Written communication was added because the skill helps students to effectively communicate technical information. Tips and tricks were taught on how to present and write effectively. Some of these tips included creating a simple but effective presentation when presenting at design reviews. Other tips included how to cite references and how to organize reports submitted for review, such as the milestone and weekly reports.

2) Activities: In-class discussion engaged the students to think about how these skills can be used and why they are important. The following questions were asked to students and discussed in class.

- Name a powerful or memorable speaker.
- Have you ever had to present to non-engineers/technical audience? What was that experience like?
- How do you explain to your family/friends/significant other what you study?
- How do you use technology to communicate? What software tools do you use?
- Do you think technology helps or hinders us to communicate?
- How has technology changed how you communicate?

In-class discussion and participation engaged students in the topic of communication. Students were asked to prepare for a general audience a short three-minute presentation about their Make to Innovate project. The rest of the students in the audience were then asked to write down two keywords they felt summarized the talk. Afterwards the class members discussed their rationales for their keyword choices, if they thought their choices best matched the talk, and why.

C. Leadership

Effective leaders inspire their peers to work towards a common goal. Many think this is an easy skill, but it is actually difficult to learn and master. This often leads to confusion and frustration for students who attempt to lead their group but are ineffective. They think that leadership is simply directing people and planning. Good leadership, however, requires more thought and developed skills that take time to learn.

1) Learning Objectives: The objectives for this skill are to introduce to students what makes an effective leader. We covered some of the traits of an effective leader, such as a good leader is one that inspires and motivates their peers towards a common goal by influencing and motivating the people they work with.

2) Activities: In-class activities included discussions and self-evaluations. During lectures, students were asked to describe their leadership style and what problems they had encountered while leading their projects. The following is a sample of questions to encourage in-class discussion.

- How do you influence your team towards positive changes?
- What changes have you recently made in your teams?
- Do your teammates look up to you?
- How did your numbers change as the activity progressed?
- How did you determine who the team leader would be?
- Team Leader. How did you decide who got what position?

In addition to the in-class discussions, students were asked to fill out a self-evaluation survey on several qualities that make a good leader, if they felt they had that quality, or if they needed to work on that quality. At the end of the semester, the project leaders' peers will then evaluate them on those same criteria so that the leaders can see how their peers perceive those qualities.

Two other participation activities were then given to the students. This included the "Jelly Bean" exercise in which students were asked to sort Jelly Beans in a group. As a group, they had to decide and sort them by flavor, not color. A group leader was selected to make the final decision in the process. Another exercise used playing cards as a trust game. The leader would select a card and the person holding the color of that card had to sit down. If the leader felt though the person was lying, they can call them out on it. However, if the team leader was incorrect, nobody wins. Both activities were used to address some of the difficulties and tough decisions a leader must make as they lead their team.

V. Data Collection Method

To obtain student feedback, monitor what the students learned, and track their progress, students were given a

template and asked to fill out a weekly journal. The template included some questions that were repeatedly asked each week. These were "How will you use what you learned today in your project?" and "What can we do to improve this?" Some of the responses received on how the students plan to use this information in their project can be seen in Figure 1. These responses were recorded after the leadership session and were collected from students with one to three semesters of experience in leading a Make to Innovate project.

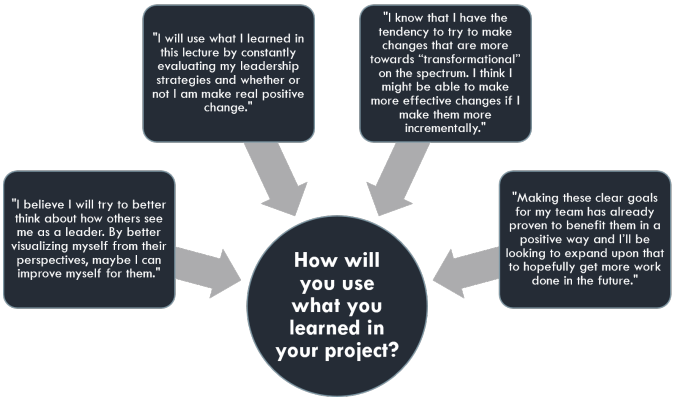

Fig. 1. Feedback from students after a leadership session on what they can use in their own projects.

VI. Lessons Learned

Based on feedback received so far and personal self-reflections on the sessions taught, we have learned some lessons that will be used to improve this course. At the beginning of the semester, we were more focused on content then on in-class discussions and activities. This resulted in the students being restless and not being engaged with the topic. Around mid-term we switched to including more activities and in-class discussions, which helped with student engagement. Another lesson learned was to better connect the dots between what the students learn to how it can be applied to their leadership activities in the Make to Innovate program.

Finally, we also learned that with the journal entries it is better to give the students a template journal with questions to answer than an open ended journal. The first couple of journal entries resulted in off-topic comments and answers that were not always very clear. Later in the semester we moved to a template for the journals, which improved the information we were gathering.

VII. Student Feedback

Student feedback has indicated a mostly positive response to learning these professional development skills. For example, a student stated "I fully believe the project lead meeting & leadership training is great concept and I hope it will be available for the following classes." Figure 2 shows a sample of some of the constructive feedback that has been received. Students reported that they felt the exercises and information were helpful and would help them as they work with their teams in Make to Innovate. However, as stated in the lessons learned, student feedback also included having more in-class discussion. Students also reported that at times the session was too long, which we plan to address by including more activities and better engaging the students.

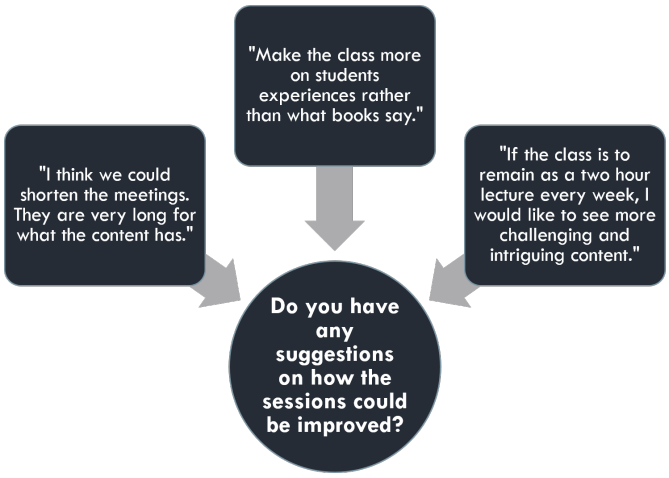

Fig. 2. Feedback from students on how the course can be improved.

VIII. Future Work

Student feedback has been positive about the material that has been covered. However, feedback has also indicated that improvements could be made. This includes more in-class activities and in-class discussion to help students better communicate their specific scenarios.

To address these feedback points, the curriculum for the course will be revised to cover the essential material but will include more in-class discussions. This will allow students to participate more directly in the class. Additional activities will be used to reinforce the material covered. These activities can also be designed so that the students can use them in their team environments to pass these skills to other students.

Finally, future work will complete the implementation of a digital badge program, which, due to time constraints, was not implemented for this pilot course. Work has been done to establish the framework for this system using Mozilla's Open Badge software running on the Make to Innovate WordPress website. Future work will fully incorporate this system into the student learning process and will be used to track the progress of students in the program.

IX. Conclusion

This work in progress is a pilot program designed to teach some professional skills to engineering undergraduate students in the Make to Innovate program. In this paper we discussed why these skills are important to engineering students. Further we outlined a pilot program that was used in conjunction with the Make to Innovate program, and we discussed in more detail the professional development skills covered so far, the skill-related activities, student feedback, and the lessons learned. Finally, as this is a work in progress, we discussed what actions will be taken to improve the course based on our observations and student feedback.

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