

Embedding Teamwork Skills in Mechanical Engineering Curriculum

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Abstract

Engineers work in teams. According to ABET, teamwork should be a major component of any engineering curriculum. Both administrators and educators agree on how important this is in preparing engineering students for their careers. However, what they do not necessarily agree on is how to get the students ready! Some try to embed this from the early stages of the curriculum and some heavily rely on the senior design course or the capstone project to achieve this. Based on data collected over the past few years in the Mechanical Engineering department at Texas A&M, we realized that our students are not ready for the capstone experience. This triggered a multi-year NSF-funded project, aiming to better equip our students with the much-needed “soft” teamwork skills before they start their engineering careers. Finding time to fit new teachings materials into an already busy and dynamic curriculum can be a challenge. Substantial changes to the current curriculum are not feasible either. Another important consideration is our class size. The Mechanical Department at Texas A&M has close to 500 students involved in the two-semester capstone projects at a given time. This means that 80 teams are formed every year, many of which are industry-sponsored, that expect a higher level of teamwork and productivity. This paper presents our ongoing work to improve our students’ teamwork skills by introducing new content to an existing curriculum. Our aim is to empower our students with an effective teamwork skill set before they graduate. To accomplish this within constraints, newly developed content focuses on introductory level growth of teamwork skills. In total, three modules of new content are introduced as one- to two-hour workshops within existing courses with team projects at the sophomore, junior, and senior levels. These workshops highlight expectations and deliverables, team communication, and conflict management, respectively. Even with the short time span, the workshops are designed to be active and engaging so that students can build awareness, gain experience, and have open discussions with their peers. All of this together can instill trust among team members. This paper will introduce the overall plan in more detail relating to the design and implementation of these modules. Preliminary results and challenges will be introduced in addition to future plans. We have already seen positive impacts on our students resulting from this work.

Introduction

Engineering projects typically require the collaboration of team members from different disciplines and expertise¹. Team members bring unique perspectives and ideas, promoting creativity and innovation². Moreover, the ability to perform in team settings demonstrates adaptability, collaboration, and leadership³ which are highly valued by employers. However, engineering programs at universities often focus primarily on technical knowledge and skills^{4,5} while students are expected to learn from various teaming experiences with little or no guidance⁶. Ideally, students could learn from both good and bad experiences, but dysfunctional teaming experiences can negatively impact a student’s view of teamwork. This combination of little guidance and bad

experiences can result in graduating students that are ill-prepared and ineffective in a team setting⁵. Therefore, engineering programs must provide teamwork training to students to develop this critical skill to prepare them for the collaborative nature of engineering projects⁷. Since large changes to the existing curriculum are not feasible, the goal of this work is to provide students with a conceptual awareness of effective teamwork skills. This will be done by scaffolding across the sophomore, junior, and senior years within the existing curriculum as students work to complete established group projects in various courses.

Methodology

The proposed methodology focuses on conceptual awareness of teamwork skills. This does not require any change or redesign of courses in the current curriculum and, therefore, avoids the typical approval procedures set by colleges and universities. The key element of the current work is based on identifying three courses in which team-based projects have decent weight. This is feasible since most undergraduate curriculums have at least one course with a team-based project at the sophomore, junior, and senior levels. In total, three modules of new content are introduced as one- to two-hour workshops. These three workshops highlight (1) expectations and deliverables, (2) team communication, and (3) conflict management, respectively. The workshops are designed to be active and engaging so students can build awareness, gain experience, and have open discussions with their peers. These workshop modules will help to establish a foundation of trust among team members. Figure 1 shows how this work interlinks these modules.



Figure 1. Essential elements of the UNdergraduates Improving TEamwork Skills (UNITES) methodology highlighting the three developed modules⁸.

Plans for each module are summarized in Table 1. We implemented all three modules in the classroom setting. The following section shares the timeline of the past and current implementation of these modules. This list has the major topics of each of these three modules:

Module 1: Roles & Expectations (Sophomore level- MEEN 210: Geometric Modeling for Mechanical Design)

- Benefits of working in teams
- Stages of team dynamics⁹
- Importance of the ‘storming’ stage
- Team charter^{10,11}

Module 2: Effective Communication (Junior level – MEEN 357: Engineering Analysis for Mechanical Engineers)

- Importance of cross-cultural communication that may cause opposite assumptions between team members due to varying cultures and background.
- Different working styles¹²
- Adapting your working style to fit the situation.

Module 3: Conflict Management (Senior level – MEEN 475: Materials in Design)

- Healthy vs. unhealthy conflict¹³
- Conflict types and examples
- Thomas-Kilmann instrument¹⁴
- “STATE” method for communicating in tense situations¹⁵

Table 1. Summary of In-Class Activities for Each Module⁸.

| Module 1 Roles and Expectations | Module 2 Effective Team Communication | Module 3 Conflict Management |
|--|--|--|
| Target Group: Sophomore | Target Group: Junior | Target Group: Senior |
| Status: Complete, but needs improvement | Status: Complete, but needs improvement | Status: In preparation |
| <ul style="list-style-type: none"> • Why and how are teams formed • Features of successful teams • Team leadership and its impact • Discussion on stages of team dynamic • Team charter development • Role-playing activity to create a team charter • Home assignment to create and maintain an actual team charter for their class project • Short reflection/assessment | <ul style="list-style-type: none"> • Team building activity • Module introduction by the instructor • Module 1 review video • Quick team activity on factors that affect effective team communication • Module 2 video on effective team communication • Working styles activity and reflection on team building activity • Short reflection/assessment | <ul style="list-style-type: none"> • Modules 1 and 2 review videos • Quick student discussion on their own experiences and best practices • Module 3 video on conflict management awareness and strategies • Role-playing exercise of healthy and unhealthy conflict with discussion on management strategies • Short reflection/assessment |

Implementation Plan

The UNITES teamwork skill development project was launched to enhance our undergraduate curriculum in the mechanical engineering department in the Summer of 2021. We started by developing a quantitative teamwork experience survey that was piloted and revised. Baseline results were collected in the Fall of 2021 before implementing the modules. The first module was developed and implemented in the Spring of 2022. We completed the mid- and post-project surveys for the module for the Spring and Fall of 2022. The surveys were used to assess the efficacy of the module.

Module 2 was introduced in the Spring of 2023, where students were assigned homework to: watch the Module 1 summary and Module 2 videos, which were made in collaboration with the Engineering Studio for Advanced Instruction and Learning (eSAIL) multimedia facilities at the College of Engineering. These videos and teaching materials would help any instructor to teach the modules concisely.

Module 3 is currently under development. Although the first two modules indirectly discuss methods to reduce conflict, the last module will explicitly tie these topics back to conflict management. In addition to helping students understand potential sources of conflict, it presents practical strategies to manage unhealthy conflict while encouraging healthy conflicts. This module was piloted at Texas A&M-Qatar over the winter break of 2023-2024. Currently, we are in the process of revising it and we are planning to implement this module in Spring 2024.

Although the data collected can help update single modules in terms of implantation and logistics, the final efficacy of the UNITES project will have to be assessed after the final implementation of module 3 by the end of Spring 2024 semester. Initial feedback and assessments show general positive impact of the project.

Summary and Conclusions

This paper presents a framework of how to embed teamwork skills in the mechanical engineering curriculum. Our approach manages to achieve this with no changes made to the overall curriculum. It is based on building and designing three relevant modules for teamwork skills training and focuses on initial identification and development of teamwork skills. Module 1 is focused on what makes a successful team. Students are taught the stages of teamwork and how the group dynamic will change over time⁹. They are asked to create a team charter in the early stages to outline the overall expectations, member roles, and consequences going forward. By bringing many of these issues to the team's attention earlier, some of the later issues can be avoided or mitigated. Module 2 is focused on effective communication after reinforcing the team charter. Students are presented with several examples of failures and misconceptions that can result from ineffective communication. Cross-cultural communication is also key in this module, as many students realize team members can make opposite assumptions due to their culture, background, or current circumstances. Without proper communication, students can begin to think the worst of their teammates. Module 3 is planned to focus on conflict management. While conflict cannot be entirely removed from an engineering project, unhealthy conflict should be minimized. Introducing modules 1 and 2 should

help teams avoid major sources of conflict while module 3 helps students navigate the scenarios where conflicts persist. Building on the previous modules, common sources of conflict, such as differing expectations, unclear communication, and lack of trust are presented to students as well as practical methods for managing conflict.

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References

1. R. J. Marandi, B. K. Smith, R. F. Burch, and S. C. Vick, "Engineering soft skills vs. engineering entrepreneurial skills," *Int J Eng Educ*, vol. 35, no. 4, pp. 988-998, 2019..
2. R. Reagans and E. W. Zuckerman, "Networks, diversity, and productivity: The social capital of corporate R&D teams," *Organization Science*, vol. 12, no. 4, pp. 502-517, 2001..
3. P. Pazos et al., "Enhancing teamwork skills through an engineering service-learning collaboration," in 2020 ASEE Virtual Annual Conference Content Access, Virtual Online, 2020..
4. A. Kolmos, R. G. Hadgraft, and J. E. Holgaard, "Response strategies for curriculum change in engineering," *Int J Technol Des Educ*, vol. 26, pp. 391-411, 2016.
5. R. Dorado-Vicente, E. Torres-Jiménez, J. I. Jiménez-González, R. Bolaños-Jiménez, and C. Gutiérrez-Montes, "Methodology for training engineers teamwork skills," in 2020 IEEE Global Engineering Education Conference (EDUCON), 2020: IEEE, pp. 587-591.
6. T. Chowdhury and H. Murzi, "Literature review: Exploring teamwork in engineering education," in *Proceedings of the Conference: Research in Engineering Education Symposium*, Cape Town, South Africa, 2019, pp. 10-12.
7. L. Ballesteros-Sanchez, I. Ortiz-Marcos, and R. Rodriguez-Rivero, "Investigating the Gap Between Engineering Graduates and Practicing Project Managers," *Int J Eng Educ*, vol. 37, no. 1, pp. 31-43, 2021..
8. Mohiuddin, M. W., & Tsenn, J., & Balawi, S., & Corleto, C. R., & Weaver-Rosen, J. (2023, June), Vertical Integration of Teamwork Skills from Sophomore to Senior and Beyond! Paper presented at 2023 ASEE Annual Conference & Exposition, Baltimore, Maryland. <https://peer.asee.org/44599>.
9. B. W. Tuckman, "Developmental Sequence in Small-Groups," *Psychol Bull*, vol. 63, no. 6, pp. 384-399, 1965.
10. P. Hunsaker, C. Pavett, and J. Hunsaker, "Increasing Student-Learning Team Effectiveness With Team Charters," *J. Educ. Bus.*, vol. 86, no. 3, pp. 127-139, 2011.
11. J. R. Aaron, W. C. McDowell, and A. O. Herdman, "The Effects of a Team Charter on Student Team Behaviors," *J. Educ. Bus.*, vol. 89, no. 2, pp. 90-97, 2014.
12. Outcome Measures Library. "Working Style Assessment." https://oml.eular.org/sysModules/obxOML/docs/id_103/01_Working-StylesAssessment.pdf (Accessed Feb. 2023)
13. P. Lencioni, *The Five Dysfunctions of a Team: A Leadership Fable*, 1st Edition ed. Jossey-Bass, 2002.
14. K. W. Thomas, "Thomas-Kilmann Conflict Mode," *TKI Profile and Interpretive Report*, vol. 1, no. 11, 2008.
15. K. Patterson, J. Grenny, R. McMillan, and A. Switzler, *Crucial Conversations: Tools For Talking When Stakes Are High*. McGraw-Hill Education, 2012.