

Vertical Integration of Teamwork Skills from Sophomore to Senior and Beyond!

Dr. Mohammad Waqar Mohiuddin, Texas A&M University

Possesses a multidisciplinary background in Mechanical Engineering (B.S. and M.S.) and Cardiovascular Physiology (Ph.D.). Currently working as an Instructional Assistant Professor in the J Mike Walker '66 Department of Mechanical Engineering at Texas A&M University. Areas of expertise and interest include biomedical and mechanical system design, electromechanical systems, computer-aided engineering analysis, and mathematical modeling of physiological systems. Before joining Texas A&M, worked in industry settings to develop various biomedical technologies, ranging from acute neonatal care to long-term space exploration.

Dr. Joanna Tsenn, Texas A&M University

Joanna Tsenn is an Assistant Professor of Instruction in the J. Mike Walker '66 Department of Mechanical Engineering at Texas A&M University. She earned her B.S. from the University of Texas at Austin and her Ph.D. from Texas A&M University. She coordinates the mechanical engineering senior capstone design projects and teaches senior design lectures and studios. Her research interests include engineering education and engineering design methodology.

Dr. Shadi Balawi, Texas A&M University

Dr. Balawi is an Instructional Associate Professor in the Mechanical Engineering department at Texas A&M. He teaches in the areas of materials, manufacturing, and design. His interests are in the areas of Engineering Design for Disciplinary STEM Educational Research, Team Formation and Team Skill Education.

Dr. Carlos R. Corleto, Texas A&M University

BS, MS, PhD in Mechanical Engineering from Texas A&M University. Experience includes 20 years in industry as a lab director, technical manager and engineering advisor, 8 years of academic experience at the assistant and tenured associate professor level, and two years as a Professor of Practice. Author and contributing author of 10 patents and multiple publications/presentations at technical and engineering education conferences. Areas of expertise and research interest include, Deformation & Failure Mechanisms, Materials Science, Fracture Mechanics, Process-Structure-Property Relationships, Finite Element Stress Analysis Modeling, Failure Analysis, ASME BPV Code Sec VIII Div. 1 &2, API 579/ASME FFS-1 Code, Materials Testing and Engineering Education. Professionally registered engineer in the State of Texas (PE).

Jonathan Weaver-Rosen

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Introduction

Importance of Teamwork Skills in Engineering Education. Teamwork is one of the critical skills for success in undergraduate engineering education and beyond. Engineering projects require collaboration among individuals with different disciplines and expertise [1]. Therefore, engineering students must learn how to contribute, communicate effectively, delegate tasks, and resolve conflicts among team members [1]. Team members bring unique perspectives and ideas, promoting creativity and innovation [2]. Moreover, the ability to perform in team settings is highly valued by employers. It demonstrates adaptability, collaboration, and leadership [3]. Engineering students can enhance their ability to complete the project effectively and gain essential skills that would serve well in their future careers by developing teamwork abilities during their undergraduate education.

Lack of Teamwork Skill Development Opportunities in Our Undergraduate Engineering Curriculum. Engineering programs at universities often focus primarily on technical knowledge and skills [4, 5]. Students participate in many group projects in their undergraduate courses but rarely receive guidance on how to work effectively as a team [6]. The lack of emphasis on teamwork skill development in the engineering curriculum can result in ill-prepared graduates working ineffectively in team settings [5]. Bad project experiences can cause students to have a negative view of teamwork and reinforce bad habits and incorrect lessons. These experiences can leave students feeling intimidated or uncertain when they enter the workforce and must work in teams. Therefore, engineering programs must provide teamwork training to students to develop this critical skill to prepare them for the collaborative nature of engineering projects [7].

Essential Elements of Teamwork Skills Development. Developing teamwork skills involves understanding the core elements, such as the dynamics of successful teams, roles and expectations, effective communication, and conflict management, as shown in Figure 1. When these elements are present in a team, its members trust each other with expectations while rolling towards success. Understanding different stages of team dynamics [8] involves recognizing changes in team members' attitudes as the project moves forward, their strengths and weaknesses, building mutual trust, and the influence of individual behaviors on the team. A team charter clearly defines the team's purpose, goals, member roles, and expectations, promoting accountability and alignment [9, 10]. Studies have shown that team charters improve teamwork, fostering mutual support, cohesion, and satisfaction, especially in newly formed teams [9, 10]. Each team should create a team charter at the initial stage of their project. Effective communication among the team members is critical for ensuring everyone is on the same page and minimizing misunderstandings. It involves expressing ideas and expectations clearly, while actively



Figure 1. Essential elements of teamwork skills

listening to others and being open to feedback and criticism. Conflict management is another essential skill for navigating challenges that may arise within the team and finding mutually beneficial solutions. It aims to restore trust and prevent further conflict escalation while sustaining dignity and encouraging understanding. Throughout these components, members of successful teams must hold themselves accountable to complete tasks and trust each other in their efforts. By recognizing these core components of teamwork skills, students can improve their abilities and confidence to work effectively in team environments and succeed in their future careers.

Our Approach

Creation of Learning Modules. To address the unmet need for developing teamwork skills of our undergraduate students, we began the UNdergraduates Improving TEamwork Skills (UNITES) project. We are in the process of developing lecture modules to integrate into our undergraduate curriculum vertically. We planned to cover this broad topic in three lecture modules. Each curriculum level, starting from sophomore, would have one lecture module discussing several relevant issues, as shown in Figure 2. Although each lecture topic is critical, we chose this specific order so that students would learn why teams are formed and the stages of team dynamics first. Then they would look into ways to communicate effectively. With the help of the first two lecture modules, it would be easier for them to identify the sources of conflicts. Then the students will learn about conflict management with the third module. We planned to teach this material across several courses so students consider effective teamwork each year and apply these skills to different team projects. Each lecture module would have active-learning components, engaging students to converse with their peers and apply what they learned. We discussed plans for each module below and summarized the class activities in Table 1. In this work-in-progress, we implemented the first two lecture modules. We have been developing the third module and will implement in future semesters.



Figure 2. Implementing teamwork skill development modules in the undergraduate curriculum

The First Module. The first lecture module would start with understanding the necessity of forming teams to solve complex engineering problems. The instructor would provide the definition of a team and discuss the features of successful teams. Students often want to be in teams with peers they are comfortable working. In the real world, however, teams undergo the ‘forming’ stage with members whose skills are necessary to complete the project [8]. Therefore, team members may not be familiar with each other. After getting to know each other, members usually move to the ‘storming’ stage, where they engage in project work and challenge each other’s boundaries and expectations [8]. At this stage, they start to understand each other by discovering their skills, weaknesses, and personalities. Teams can only move to the ‘norming’

and ‘performing’ stages after successfully going through the ‘storming’ stage. [8]. However, student teams often do not recognize the ‘storming’ stage and develop a distaste for teamwork. Therefore, an important aspect of effective teamwork entails understanding various stages of group dynamics in terms of both team situation and individual temperament [8]. The students would meet as teams for the first time, exchange contact information, and discuss their weekly schedules. This lecture would make students aware of the different stages of team formation, enabling them to counter the ‘storm’ [8] and seek its constructive sides as they advance their project. The instructor would then have a live discussion on the team charter and its benefits [9, 10] and start an in-class activity by providing a scenario of a hypothetical team with various characters with different availability, working styles, communication styles, and expectations. The students would be asked to role-play those characters, work through the challenges, and create a team charter. A typical team charter contains the project’s mission and goal, each member’s roles and expectations, including operating guidelines and performance norms [9]. In the end, student teams would receive a homework assignment to build a team charter for their class project.

The Second Module. People come to the team with different experiences, perspectives, working styles, and communication styles. The second lecture module emphasizes the importance of effective communication to maximize team performance since poor communication is one of the top reasons for team failures [11, 12]. Prior to any lecturing, the instructor would ask students to experience the “Lost at Sea” activity [13]. This activity involves a small group of students working individually and as a team to solve a low-stakes problem with little time and instruction. During the activity, some students may speak loudly and take charge, some may stay quiet and go with the flow, and others may struggle to have their voices heard. Students’ experience in this activity should set the stage for the rest of the module. After this activity, students would receive more formal instruction on strategies for effective communication and the potential consequences of poor communication via prerecorded videos. Instructors would also lead a live discussion asking students to reflect on their activity experience considering this new information. To end the module, students would complete the “Working Styles Assessment” [14] to think introspectively about how they naturally work. Students will also share their working styles with their teammates. This activity has three main goals: 1) students should gain an appreciation for the existence of different working styles, 2) team members should understand each other’s primary style so that they can work together more effectively, and 3) students may recognize the need to adapt their primary working style based on those around them and their role on the project. Students will again be asked to reflect on their experience in the first activity. Teams may have learned that one member is naturally inclined to take charge; others may have learned that they have multiple drivers fighting for control – or nobody wanting to lead. In any case, we want the students to start understanding each other earlier rather than waiting for their first assignment due date.

The Third Module. The final senior-level lecture module would focus on conflict management. This module builds on the previous two modules by giving students practical tips and tools to effectively manage issues that could arise in higher-stakes and longer-term project teams. The first step would be to help students understand that not all conflict is destructive. Working through disagreements can help teams develop strong, shared understandings of the problems at hand. Additionally, debate centered around trust can push a team toward better ideas

and solutions [15]. In this lecture, we will introduce students to the different types of conflict via the Thomas-Kilmann conflict model [16] to help them identify unhealthy conflicts. Then students will learn to confront these types of conflicts through effective communication and understanding of different working styles (Module 2). We will introduce the STATE method for conflict resolution [17] to tackle unhealthy conflicts arising from situations, such as misunderstandings, lack of trust, and assumptions. The goal is to encourage students to listen and seek to understand others during the conflict. If all students stubbornly believe they are correct, things cannot improve. Additionally, students will look more in-depth at setting team expectations early in team formation as part of a team charter (Module 1), including accountability plans and potential consequences for team members not meeting expectations. We plan to design a role-playing exercise for the whole class or smaller subgroups to give students a tangible example of conflict, followed by a discussion of what went wrong. In the end, students will learn that not all conflicts can be avoided, nor can all conflicts be resolved. They should, however, manage conflicts such that all members of a team can form a common understanding to remain productive toward the overall team goals.

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

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 	<p><i>Tentatively:</i></p> <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

Assessments and Student Feedback. We would implement these lecture modules in three courses with semester-long team projects. Instructors would teach the respective lecture modules before the projects are launched. We plan to assess the UNITES project in two ways. First, students would complete a short three-question reflection survey about their learning experience at the end of each module. These questions would provide us with an understanding of the critical items learned from the lecture, whether we missed any relevant topic, and what they want to utilize from the lecture. We would use the feedback to make improvements to the module. Second, we would ask students in each course to complete mid-project and post-project surveys.

We would include demographic, previous teamwork and leadership experience, and training questions in both versions of the survey. They would also include quantitative questions to capture the students' perspectives of their team project experience, adapted from Ullman's Team Health Assessment [18]. We would use the survey results to determine if there are improvements in the students' team experience.

Accomplishments to Date and Reflections

We launched the UNITES teamwork skill development project to enhance our undergraduate curriculum in the mechanical engineering department in the Summer of 2021. We developed the quantitative teamwork experience survey, then piloted and revised it. We collected the baseline results in the Fall of 2021. At the same time, we also developed the first module and taught it for the first time in the Spring of 2022. After its implementation, we realized that the lecture and the hands-on activities took longer than expected and that the lecture timing and material were dependent on the instructor. We refined the module content to improve the time needed to complete it on time. We decided to change the lecture format from traditional active learning to workshop style to increase student engagement and provide more structure to the module. The hands-on activities allow students to practice what they learn and reflect on their experiences. We completed the mid- and post-project surveys for the module for the Spring and Fall of 2022. At the time of writing this paper, we have not yet implemented the mid-project survey for the Spring of 2023. Our experience with Module 1 not only helped us improve it but also helped to create the remaining modules more effectively.

We introduced Module 2 for the first time in the Spring of 2023. Unfortunately, the module was implemented differently than planned due to inclement weather. For one section, an instructor facilitated the shipwreck activity [13] during class time, followed by a discussion with students (all totaling about 20 minutes). Then students were assigned homework to: watch the Module 1 summary and Module 2 videos, complete the Working Styles Assessment [14] worksheet, and complete a reflection. Students turned in these reflections for a small completion grade toward their project. For the other class section, there was no time for the shipwreck activity [13] in class. However, the instructor assigned the same homework after a brief introduction during the lecture. Reflection responses are currently being collected and processed.

We have been collaborating with the Engineering Studio for Advanced Instruction and Learning (eSAIL) multimedia facilities at the College of Engineering to prepare the videos associated with these learning modules. These videos and teaching materials would help any instructor to teach the modules succinctly.

Conclusion and Future Work

To date, we developed two learning modules that cover characteristics of successful teams, different stages of team dynamics, the importance of maintaining a team charter, and effective communication. We are reviewing the student feedback and will use the information to improve the modules. Also, we are currently developing Module 3. Although the first two modules indirectly discuss methods to impede conflict, the last module will explicitly tie these topics back to conflict management. In addition to helping students understand potential sources

of conflict, it will present practical strategies to manage unhealthy conflict while encouraging healthy conflicts. We hope to implement this module in Fall 2023 or Spring 2024. With the limited time allocated for these modules in each class, our plan is to make sure that students are well aware of these issues and provide them with a good starting point for their continuous learning and improvement of their teaming skills.

The ultimate goal of the UNITES project is to complete the learning modules independent of the instructor. Furthermore, we will convert the lecture notes into videos. This will allow us to share the complete learning modules with the global engineering teaching community through our library system.

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