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Work In Progress: A Teamwork Training Model to Promote the Development of Teaming Skills in Chemical Engineering Students.

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Introduction

Multiple studies highlight how the modern work environment increasingly requires teams that are multidisciplinary, diverse, and dynamic [1]–[5]. Organizations must be rapid to adapt and innovate in their efforts to remain competitive and create long term value for their stakeholders[6]. It has been previously discussed that effective teamwork promotes innovation, improves adaptability, enhances organizational flexibility, and reduces employee turnover [2], [7]. As a result, organizations dedicate great efforts towards the creation of work conditions that facilitate value generation in collaborative team activities that occur in this fast-moving work environments [7]. Within this framework, the understanding and management of workforces has recently shifted towards work models that are inherently global and that encourage fluid work structures; this shift highlights the increasing importance of teamwork in the achievement of organizational effectiveness [6], [8], [9].

As organizations and workforces evolve, the technical competencies and job opportunities of engineering students are also constantly evolving [3]. Nowadays, engineering students are pursuing careers in more diversified areas that possess fluid work structures, and that require engineers that are quick to adapt to change and effective at facilitating multidisciplinary collaborations [3], [5], [10]. In this context, communication and teamwork are critical to the success of early career engineers; these capabilities are a fundamental aspect of career growth and an integral trait of leadership [4], [10]–[12]. The ability to communicate effectively, to demonstrate teaming skills, and to work in dynamic teams is increasingly important, and must be considered a priority in engineering programs as they try to better prepare students for their postgraduation careers.

Hence, we propose chemical engineering undergraduate programs must find ways to adapt to these fast-moving work environments as they aim to close the knowledge gaps that exist between industry needs and current teaching offerings in engineering curricula [4], [5], [13]. Recent engineering graduates are often underprepared for fast changing workplaces that are centered around teamwork and that require adaptability and flexibility [3], [5], [11]. We suggest this gap can be reduced by creating an effective model to train students in the development of teaming skills and by changing their perception of teamwork. The proposed teamwork training model emphasizes the skills and capabilities that will help students perform in any team. Our work focuses on the flexibility of developing skills that will allow students to learn how to team (i.e. teaming skills), rather than on teambuilding exercises that promote the power of traditional rigid team structures[1], [7].

The overall objective of this work-in-progress is to propose the utilization of modern practices in teamwork and teaming education to effectively prepare chemical engineering students for a changing work environment that centers around collaborative activities. In the following sections, we will detail our training model development as we have created lectures and practical class components focusing on the acquisition of teaming skills and the practice of effective teamwork in a Unit Operations laboratory course. The research question this study aims to

answer is whether the perception, interest, and attitude of chemical engineering students towards teamwork can be altered by purposely including teamwork training as part of their undergraduate education. As part of this study, we will also investigate the effectiveness of this model in promoting teaming skills in chemical engineering students.

Model Background

As detailed in the foregoing, despite the mounting evidence that teamwork is a fundamental skill for new engineers, most chemical engineering students tend to see the development of teaming skills and the training in effective teamwork as a requirement to complete a course rather than a necessary skill in their professional careers [4], [5], [11]. It can be very challenging for engineering educators to promote interest in skills that are often seen as unnecessary by students, and for the most part, few engineering instructors have been trained in teamwork as part of their education in academia [4], [11]. Moreover, the perception engineering students usually have about teamwork is further cemented by unfulfilling teamwork experiences, these experiences are often the result of assuming students will acquire teaming skills by being assigned to work in teams as part of a class, and that students will know how to work with others without receiving further training to cultivate these skills [4], [5].

Thereupon, our initial effort will center on changing the student perception towards team activities. Instructors must be intentional in presenting students with evidence of the importance of teamwork for new engineering graduates, explaining how these skills are crucial in high-skilled technical jobs, and emphasizing studies that highlight emotional intelligence as a driving factor in career success[7], [12]. In addition, our second goal will be to help students recognize they are most likely to work within fluid work structures that require a high degree of adaptability where smart skills are essential to career growth [14]. Our last focus will be on emphasizing the fact that similar to any other engineering skill (e.g. calculus, thermodynamics, etc), teamwork and teaming skills can be acquired and improved through their undergraduate experience with intentional practice.

To promote the learning and practice of these skills, we utilize an approach that focuses on teaching and promoting teaming skills in chemical engineering students (i.e. how to team), rather than on team building activities which has been the focus of previous reports [5], [10]. We propose that engineering programs do not need to reinvent teamwork education; we believe that the focus should be on emphasizing teamwork, teaming skills, and leadership practices as a central element of professional success and accomplishment. Our approach tailors the use of these concepts to target effectively the skills needed by engineers in the modern work ecosystem. Our objective has been adapting the existing teamwork and teaming knowledge to a chemical engineering centered context and, by this effort, we intend to promote the creation of future engineering leaders that have developed these skills as part of their undergraduate education.

Model Development

Teaming has been defined as a dynamic activity determined by the mindset and practices of teamwork, rather than by the design and structure of stable and well-designed teams [7]. In our model, we are not proposing that traditional teamwork training must be avoided, in contrast, we

are proposing that the focus must be on the development of skills that will allow students to perform well in any team experience they will encounter in their profession.

Our model emphasizes the development of the key aspects in effective teaming proposed by Edmonson[7], we suggest these must be incorporated in the training of new chemical engineers:

- Communication: This is an interpersonal behavior. It means speaking up and promoting discussions that incorporate multiple perspectives and heighten individual knowledge.
- Collaboration: This requires cooperation, mutual respect, effective feedback, and common goals within the team.
- Experimentation: This aspect is related to the independence created by uncertainty; it required teams that assess and learn from their actions.
- Reflection: Teams need to be critical of their results and they need to be ready to implement the changes necessary for their improvement.

We propose this model fits best the current needs of chemical engineering students as the concept and practice of teamwork have shifted in modern organizations. Effective teamwork and the cultivation of teaming skills must be approached as a dynamic activity that occurs within fast-moving work environments that promote flexible team structures. We discuss our planned implementation of the model in the following section. In addition, we describe our exploration in finding ways to promote these aspects of teaming in a laboratory course.

Model Implementation

We plan to implement our training model to promote teaming skills in chemical engineering students in a senior level Unit Operations laboratory course (referred as "the projects laboratory") in a research university in Texas, USA (referred as "the University"). This laboratory course is a core-course in the chemical engineering program at the University. The class must be taken by all students that intend to obtain an undergraduate chemical engineering degree. Registration in the course can fluctuate slightly every term, nonetheless, it is approximately 70 to 90 students per semester. The course is offered twice a year to students that have completed all prerequisites to enroll. In total, 150 to 160 students complete the laboratory every academic year.

We have selected this senior level laboratory course to implement the teamwork training because the course format favors and facilitates the application of the proposed methodology; in addition, chemical engineering students are most likely to readily adapt to the training and to focus their efforts towards activities that positively promote their professional development and help their transition to the workforce. The chemical engineering projects laboratory pursues the fulfilment of learning objectives that aid students in the acquisition of the skills necessary to the professional practice of chemical engineering. The course structure, objectives, experiments, assignments, and manuals have been formatted to promote collaboration, potentiate technical discussions, and help students gain teaming skills. To further facilitate the accomplishment of the course objectives and promote the practice of teamwork, all activities, experiments, and assignments are completed in student teams. Students are organized in teams of 3 or 4 assigned randomly by the instructors; these random team assignments try to best simulate the typical team formation conditions in postgraduation experiences [15].

The projects laboratory is divided in two interdependent sections: (a) students complete four pilot-plant type laboratory experiments for which they produce different report types (referred as "standard experiments"), and (b) they simultaneously develop a research project (referred as "class projects") that is self-directed which is the focus of our teamwork training. During the completion of class projects, students propose their own research, create individual and group proposals, build their own theory, and complete their experiments in their proposed scheduled; in addition, they report to a teaching assistant who acts as a project manager. The experimental section of the class projects is performed during the second half of the semester. The course culminates with a poster session where students present and discuss their experimental results. Thus, the teamwork training will target the application of teaming skills during the class projects as we believe this course format effectively simulates the engineering work environment.

Lessons introducing students to the principles of teamwork and teaming skills will be completed in the lecture component of the laboratory course. As described in the aforementioned, the focus of the training is on the class projects section of the course, however, these lessons can be already applied by students in their standard experiments (and in other classes). All teamwork lectures will be completed in the initial weeks of the semester, that is, before students present a proposal for their research project and before they perform any experimental work related to their class projects. Nonetheless, during this time they are already working in their teams in the completion of their assigned standard experiments. Approximately 30 minutes of the lecture time will be dedicated weekly for 6 weeks to complete our teamwork training. The following topics will be detailed weekly, parentheses indicate the topics covered each week:

- Teamwork skills and smart skills for engineers. (Week 1)
- The evolution of teamwork in the workplace. (Week 1)
- Definition, importance, and characteristics of teams in the workforce. (Week 2)
- Elements of team success. (Week 2)
- Introduction to team building. (Week 3)
- Teaming and the domain of teaming skills. (Week 3)
- Team leadership in global teams. (Week 4)
- Team contract and the GPRI Framework (Goals, Roles, Procedures, and Interpersonal Relationships). (Week 4)
- Effective feedback. (Week 5)
- Peer-review and assessment of team performance. (Week 6)

During these lectures as well as during the laboratory experience, active learning strategies must be used to promote discussion and participation amongst teammates. The instructor must take an active role in promoting communication and creating an environment that invites psychological safety. Discussion questions and open class sharing are implemented to ensure constant communication within each team. Our training strategy aims to emphasize the four pillars of effective teaming (i.e. communication, collaboration, experimentation, and reflection [7]) by incorporating them into all components of the laboratory experience.

As we have previously defined, the model focus is not on team building but rather on the cultivation of teaming skills that will allow our students to work effectively in any team postgraduation. However, the promotion of the classical 5 elements of team success: psychological safety, dependability, structure and clarity, meaning, and impact, is inherent to the

class activities described above [5], [16]. Furthermore, an indirect but important byproduct of the teamwork experience will be that students are exposed to the stages of team development (i.e. Forming, Storming, Norming, and Performing) proposed by Bruce Tuckman. Tuckman's theory suggests that even short-term laboratory experiences can be enough to promote teambuilding and create effective teams that perform well[17].

At the end of the semester, the laboratory experience concludes with a poster presentation of the class project. The first hour of this session will be utilized as a time to promote reflection of the teamwork experience each student had during the semester. Students will be assigned with a questionnaire a few days in advance to reflect on their teamwork project experience. This questionnaire will help them think about their team's performance, their individual contributions within their team, and how their direction, structure and mindset allowed them to complete the project successfully. Their individual answers will be discussed in this final session within their group and later openly shared with the class in an open forum format. In this open forum, students reflect on areas to improve, and they are invited to share their understanding of their performance, while summarizing their strengths and actions to take to become more effective in future professional experiences.

Our end goal in this study will be understanding the effect of our training over the student perceptions of teamwork and its effectiveness in producing such changes and in successfully training students. To this end, we will implement a mid-semester survey that aids to clarify the contributions of the course to the professional development of students and their attitudes towards teamwork. The survey will be administered in Qualtrics during regular class time and it contains three Likert-scale questions and one open-ended question to obtain information and feedback on the training model effectiveness. Two key questions in this survey will also be included in the end-of-semester Course-Instructor survey administered by Testing and Evaluation Services at the University level. All survey data is collected electronically, and students are asked to provide consent for the data to be used for education research purposes. Participation in the surveys is voluntary. Results will be analyzed using a statistics software package to discover trends and facilitate data sets comparison. Survey results are compared to results obtained in previous years to form additional conclusions. Our plan is to compare the version of the course including teamwork training to instances when the course had the same format, structure, and instructor but no teamwork training was offered. We will also utilize answers to open-ended questions in mid-semester and end-of-semester surveys to compare and analyze the attitudes towards teamwork and the contribution of our training to the professional development of students. This comparison will help us understand better the improvements accomplished in student perception; nonetheless, it is important to note that previous versions of the course and survey did not target our current teamwork objectives, as a consequence, any comparisons will be at the qualitative level.

Current Status and Future Work.

The current laboratory course format (i.e., with or without teamwork training) was first implemented in Spring 2021. We have utilized the same format of the class, a similar student population, and the same instructor teaching the course every semester starting in Spring 2021.

The laboratory course version that includes our teamwork training method was first implemented in the course in the current academic year (2022 – 2023).

Survey data from previous iterations of the course (i.e. before Fall 2022) has captured informative student comments regarding their perception of teamwork:

- "I wish we could have chosen our own groups. I ended up having a group that did not do the caliber of work I would have liked." (Spring 2022)
- "Working in groups with random students is very challenging" (Spring 2022)
- "This teamwork experience can be used in interviews. I wish we had more serious teamwork in courses earlier on." (Fall 2021)
- "This [course] would be somewhat doable, except for the fact that the majority of assignments were group work. Having so many group assignments constantly due increased the workload as assignments could not be completed on my own time. Instead, I would have to coordinate with other group members to meet/work on assignments." (Spring 2021)

Consistent with other reports, students without proper teamwork training can have a negative perception of the benefits of working in teams; moreover, they often lack effective teaming skills to solve conflict, create a collaborative environment, set realistic deadlines, communicate expectations, and agree on a commitment towards a common goal.

Based on informal in-class discussions during the first implementation of the training, students have responded positively to our teamwork improvement efforts. Anecdotally, the author of the manuscript noted that, if properly guided, most students effectively perceive the value of teamwork and teaming skills in their laboratory experience and future engineering careers. As depicted above, this contrasts with previous iterations of the course where students mentioned working with others as one of the most challenging aspects of the laboratory.

We plan to continue this study and collect data, analyze results, and contrast changes over the academic year. If the study results are successful, we will propose the implementation of this training during the freshman and junior years of the chemical engineering program. We hypothesize that the development of this model over several years in the undergraduate experience will lead to the best possible results and will ensure the intentionality of students towards the improvement of their professional skills[18].

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