Work in Progress: Are Project Teams Actually Developing Professional Skills?

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Introduction

Professional skills have been praised throughout engineering education as vital for engineering students to succeed in the professional world (Chaibate et al., 2019; Rao, 2014). Academia has also noted the importance of developing professional skills in ABET Student Outcomes (ABET, 2021, pp. 8–9) and the Educating the Engineer of 2020 report from the National Academy of Engineering (2004). Experiential learning is one way that academia has changed in response, which can take place inside and outside of the classroom. A literature review of experiential learning found that most experiential learning research centers on in-class programs and courses and has assessed a range of skills including technical, professional, and personal outcomes (Jamison et al., 2022). However, curriculum change takes time. Engineering curricula are already extensive and time-consuming, so adjusting or adding more courses is not always possible. Therefore, out-of-classroom experiences have emerged as another way to develop the skills necessary to create engineering professionals.

Many out-of-class activities have been shown to give students the opportunity to learn professional skills including service-learning, internships, co-operative education, engineering societies, and design competition experiences. Students involved in service-learning experiences perceived themselves as having more experience with professional skills than those who did no service activities (Litchfield et al., 2016) and they credited their service-learning experience as the main space where they learned and practiced professional skills (Carberry et al., 2013). Students who participated in an internship or cooperative education experience, an engineering design competition, and professional societies had significantly different design, analytical, and group skills abilities (Strauss & Terenzini, 2007).

Project teams, sometimes referred to as engineering design or competition teams, stand out in the literature as being particularly effective in developing professional skills. Project teams are student-operated, co-curricular activities that often follow competition guidelines that are designed by engineering organizations such as the ASCE Concrete Canoe Competition and the University Rover Challenge. The projects expand on engineering coursework and offer opportunities for students to learn new technical skills. In addition, the student-run team structure requires students to communicate, organize, and facilitate their teamwork which gives them opportunities to develop professional skills.

Project teams, in general, are recognized as a great way to develop professional skills. Previous research has focused on professional skills that stem directly from ABET criterion. For instance, studies have used the ABET criteria as a guide to see which outcomes students are practicing on project teams (Bland et al., 2016; Koehn, 2006). While others investigate particular skills such as leadership and ethics that are part of ABET (Burt et al., 2011; Wolfinbarger et al., 2021). However, *how* project teams facilitate that development is not clear. In their literature review, Johnson and Main (2020) noted how the quality of effort, using skills in authentic environments, and peer interactions all impacted students' development of skills and abilities in experiential learning settings. Wolfinbarger et al. (2021) noticed how students on two engineering project teams – with very different internal structures – measured very differently in their leadership

stages. This study investigates what mechanisms are in place to facilitate the development of professional skills by investigating the following research question: *How are undergraduate students in project teams developing professional skills?*

Project teams are very diverse in their internal structures. Because project teams are student-run, a single student has the ability to affect the organization and internal structures of their specific project team. Over time, different teams become known for various aspects such as being inclusive, delivering a technically challenging project, or having a highly demanding schedule. Hinkle and Koretsky (2019) described three teams with varying structures and the possible effects of those structures on students. Project teams can organize sub-teams, elect leaders, and schedule meetings in different ways that can affect what benefits students receive from participating. Therefore, by looking at project team structures researchers can study a wide range of mechanisms because they represent a wide range of possible organizational structures.
Two teams are represented in this study, the Rocket Team and the Boat Team. The Rocket Team is known for its complex project with numerous technical systems that are designed and coordinated. The team is organized into seven sub-teams and team members dedicate a lot of their time working in their specific subteam. The team does not follow a national competition but rather sets its own goals for the year. Many alumni from the Rocket Team are working in industry and remain in contact with current members to help them with their project work. In contrast, the Boat Team is organized into two main subteams and actively recruits students outside of engineering majors. The Boat Team competes in national competitions; therefore the members follow the guidelines, documentation, and design goals that the national organization establishes. There is also more focus on team building and less self-directed work compared to the Rocket Team.

Methods

Students were recruited directly from their university project teams. The first and third authors attended a project team lead meeting to introduce themselves and the project. After the meeting, the director of the project team workspace sent a follow-up email to the leaders of the project teams and requested that they forward the email directly to their teammates. The students who were interested completed an interview consent form that was linked in the email. The consent form asked students for their contact information, what kinds of mathematical models are performed on their team, and to select five professional skills that they associated with their project team.

The Student Involvement Framework (Fisher et al., 2017) was used to create the list of professional skills that participants could choose from in the consent form. The list was also referenced and displayed during the interview. In their paper, Fisher et al. (2017) identified professional skills from extra- and co-curricular activities that were available at an institution. The skills were then separated into categories. The Project Team category, which was composed of 14 groups, contained 18 out of the possible 20 skills. The majority of the professional skills overlapped with ABET Criterion 3 (ABET, 2021), but all skills were deemed important for success in the workplace by the authors. Looking beyond the ABET criterion is important when considering the future of engineering education. ABET represents one possible list of important abilities for students to learn while in college, but it is not an exhaustive list of every skill that

students need to succeed in their chosen professional role. Therefore, understanding how students are developing skills that lay outside of ABET is also important.

The interview protocol was designed to correspond with Experiential Learning Theory's (ELT) learning cycle (A. Y. Kolb & Kolb, 2009; D. A. Kolb, 1984). The learning cycle is composed of four parts: concrete experience, reflective observation, abstract conceptualization, and active experimentation. During the cycle an individual experiences an event (concrete experience), reflects on said experience (reflective observation), congeals said reflections into abstract concepts (abstract conceptualization), and plans on using the concepts in future situations (active experimentation). The theory was selected to frame how/if students are learning professional skills experientially through their participation in engineering project teams. Since project teams use experiential learning to teach technical knowledge and skills, we wanted to see if the same was true for professional skills.

The interviews were semi-structured and lasted approximately 60 minutes. Two students were selected to partake in the interviews based on their responses to the consent form. At the beginning of the interviews the students selected pseudonyms, Darcy for the Rocket Team member and Perry for the Boat Team member, and were reminded that they could choose to withdraw from the interview at any time or abstain from answering any questions. Both participants held officer positions on their respective project teams, identified as male, and were upperclassmen, one describing himself as a senior and the other as a junior.

The transcripts were coded by the first author with the four components of the experiential learning cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation. By mapping out what aspects of the experiential learning cycle are currently present in project teams in relation to professional skills, we can observe if students are completing all stages, thereby experientially learning professional skills. Each time a stage was coded the corresponding skill that was mentioned and the setting it was developed in were recorded. The analysis took a conservative stance on coding. There were some instances where a student seemed to imply that they had completed an iteration of the cycle, but if each stage was not explicitly noted in the transcript, that cycle was not considered complete.

Results

Abundant examples of **concrete experiences** were recorded for both individuals. When asked why the individuals chose the specific professional skills on the consent form, both responded with examples of ways that they personally practice the skills on their project teams and how others demonstrated those skills. Darcy from the Rocket Team discussed how his practice with communication skills stems from more than one experience stating, "Public speaking was also a big one, mostly in our, you know, [design reviews] and our presentations that we give also like we do lots of documentation…because we want to make sure that knowledge gets passed down." More personally, his officer position put him in situations where he facilitated conflict resolution between team members which strengthened his interpersonal communication skills. Similarly, Perry on the Boat Team noted how he gained interpersonal communication skills from his experience of being the only individual from his discipline on a multi-disciplinary team and how the technical proposal that is required for the national competition gave team members

experience in written communication. He also discussed how leaders on the Boat Team used time management skills to organize efficient meetings and practiced organizational management skills when they distribute the team's workload amongst new members to create an effective and productive workflow.

Both Perry and Darcy also mentioned elements of **reflective observation** in their interviews. Darcy discussed his personal lack of time management skills. He mentioned his current method of time management was not a good system and repeatedly reflected on how the whole team would benefit from better time management skills. Later in the interview, he also reflected that the team would benefit from organizational management skills to more evenly distribute the workload to newer members. Where Darcy reflected on skills that could be improved, Perry reflected on the Boat Team's successes when it came to skills they were practicing and developing. Perry noted how one of the leaders on the team had excellent time management skills and how it made the whole team run well. He also reflected on how he learned to communicate on a multi-disciplinary team by changing his diction and using less jargon when working with his teammates to improve communication.

The other two pieces of the ELT cycle had much fewer coding instances. There were no examples of **abstract conceptualization** coded in either transcript. Meanwhile, **active experimentation** was only coded in Perry's interview. Perry explained how he could apply his communication skills and further develop them in his professional career because he expects to write technical reports in his future job. Also, when asked about interpersonal communication he had practiced on his multidisciplinary team he stated that the skill "is really important when I get into industry…I'm going to have to be working with people across all the different disciplines." In both instances Perry planned on using professional skills he developed on project teams in future scenarios.

Discussion

Experiential Learning Cycle

The students had numerous examples of concrete learning experiences and reflective observations for professional skills. They both clearly articulated their personal experiences with specific professional skills and explained how other team members were observed using professional skills. They also reflected on particular skills that either they or their team members performed well or needed to improve. The interviews confirm that project teams provide situations where they are able to practice professional skills through concrete experiences and observe and reflect on the skills.

However, the abstract conceptualization and active experimentation stages of the ELT cycle were lacking in the interviews. We recognize that only two students were interviewed and that the interview protocol may not have effectively prompted students to think or talk about each stage. In particular, abstract conceptualization was difficult for interviewers to ask about and for students to verbalize, thus it's suspected that students may have been doing this part of the cycle but did not explicitly describe this stage in their interviews. The students discussed their process of learning professional skills on project teams in ways that implied they were completing the entire experiential learning cycle. For example, when Perry was asked how students learn about

professional skills he replied “Doing it, watching others and going ‘oh that didn't work’ or going ‘oh that worked really well, that meeting went really well, let's do that again.’” This quote aligns with ELT’s cycle where students are experiencing the skills, reflecting on the outcomes of those skills, and planning on how to use them in the future. Therefore it implies that project teams are opportune spaces to teach and develop students’ professional skills experientially. However, the students did not verbalize how they were completing each stage. Because students are not completing the entire experiential learning cycle on their project team, we suspect that students are not developing and learning professional skills effectively on project teams.

This finding illustrates an area where scaffolding is needed for students to learn professional skills experientially, specifically the abstract conceptualization and active experimentation stages. For example, when Darcy was prompted to describe skills he thought he should develop for his career he chose time management and disciplinary knowledge. When he discussed time management skills, he described his current system of setting goals in the morning and his issues with the system. By contrast, when he talked about disciplinary knowledge he described his lack of experience with classes in a specific field, reflected on why he wanted to understand the subject better, discussed his lack of knowledge of the topic, and detailed his plans of getting a master’s degree in order to fill that specific gap in his technical knowledge. Darcy made a plan to improve his technical abilities, but he did not do the same when it came to professional skills. He had the opportunity to discuss active experimentation for his professional skills but he did not. One possible explanation is that Darcy did not know about resources he could use to improve professional skills like time management. He knew where to go for disciplinary knowledge, but not professional development. If project teams are not providing scaffolding for students to complete all stages of ELT’s learning cycle they are depending on external resources to aid students in developing professional skills. But what if there are no external supports or resources to aid in completing all stages of the experiential learning cycle?

These results can inform what types of initiatives universities can implement to ensure that students in extra- and co-curricular activities are developing professional skills in a meaningful and efficient way. Student project teams have various organizational structures, regulations, and requirements for their competitions and projects. Universities can learn what mechanisms are already encouraging the development of professional skills so they can adapt and apply them in other settings such as project-based courses to benefit more students.

Project Team Structures

With respect to the structures that were connected to professional skills, there were numerous mechanisms on the Rocket Team and Boat Team that students connected directly to specific professional skills. Both students connected the deliverables of the team to communication skills and related their work on a team to interpersonal communication skills. Darcy connected his team’s design review presentations to public speaking while Perry connected his team’s technical documentation for the national competition to developing written communication skills. For interpersonal communication, Darcy’s position on the team led him to facilitate conflict resolution between team members while Perry’s position on a multi-disciplinary sub-team put him in situations to practice his interpersonal communication skills with students who were not in his major.

Time management and organization management were also discussed by both students. Perry mentioned time management in reference to keeping meetings time-efficient. By contrast, Darcy talked about his lack of time management skills and the shortcomings of his techniques for time management. On a similar note, Perry talked about the Boat Team's impressive organizational management abilities while Darcy noted his team's overall lack of organizational management stating that "a big problem I see in the [Rocket Team] is that the workload is not evenly distributed like there are maybe like 10 or 12 people that know a lot and they're just basically doing the entire project themselves." The stark contrast between the development of these skills begs the question: what elements of the project teams are aiding or inhibiting the development of these skills?

The authors considered how individuals' leadership positions on the team could affect which skills students had developed on their project team. When directly asked if their officer position on the team impacted the skills that they developed, both students rebuffed the idea. Darcy stated that the extent of involvement students had on the team impacted their skill development more than their official position while Perry thought the sub-team that individuals worked on would change the skills they developed.

Implications for Future Research

The current study only represents two individuals on two different project teams. Not only was it a small sample, but the two participants were both male, upperclassmen, and in officer positions. Students who are new to the team, have different demographics, or are general members may have very different experiences than the two included in this study. In our future research, we will expand our work to look into different project teams and a larger range of students on project teams in order to better understand the possible structures of the organizations and their benefits related to professional skills. Also, abstract conceptualization was difficult for students to verbalize and difficult for researchers to formulate questions about. Future work will focus on effectively eliciting students' responses about this specific stage in the experiential learning cycle.

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