Supporting Successful Teams: Preparation, Team Formation, Teamwork, and Team Health

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Now in its ninth year, Franklin W. Olin College's Senior Capstone Program in Engineering (SCOPE) has grown and evolved into a stable, industry-sponsored capstone program. Based on feedback, sponsors are highly satisfied with project results and the majority of students feel they have had rewarding and challenging engineering experience. We have found that one of the most important factors to which students attribute their success is the team experience. In this paper, we discuss the preparation for advanced teamwork that students receive in their first three years of the curriculum, our unique team formation process, the role of peer- and self-feedback, and our approaches to supporting teams.

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Industry calls for students who are not just technically excellent but also able to communicate effectively and work on teams. In addition, there is evidence that learning outcomes are improved in collaborative learning environments. This has led to great interest in incorporating team-based work into engineering curricula. Successful outcomes should not be expected by simply assigning students to work in teams. They require directed skill building.[1,2] At their best, good teams can perform far beyond the sum of the individuals.[3] In order to discuss teamwork in the Senior Capstone Program in Engineering (SCOPE), it is important to understand not just what we do to support teamwork during the SCOPE experience, but also how the curriculum at Franklin W. Olin College of Engineering (Olin) prepares students prior to their senior year.

To over-simplify, a common model of engineering education is one in which students take disconnected disciplinary courses, are primarily exposed to problems with defined answers, and skills such as teamwork and communication are not emphasized until students are expected to perform open-ended group work for the first time in a final capstone course. In contrast, SCOPE is a true capstone to the curriculum in the sense that students, through previous, shorter-time-scale projects, are prepared both technically and teaming-wise to take on a year-long, open-ended project. The interpersonal and project management skills students need for SCOPE, and their work in the future, have been scaffolded throughout the curriculum. The success of the program is very much tied to the skills and attitudes students develop prior to the senior year as well as to the technical material they are have mastered. This paper describes the preparation students receive, the SCOPE program, team formation, supporting teams, and the role of feedback.

Preparation and SCOPE Within the Curriculum

Olin's mission is to prepare "students to become exemplary engineering innovators who recognize needs, design solutions and engage in creative enterprises for the good of the world." As a small (~350 students), residential undergraduate-only college, Olin has a close-knit culture both in and out of class. A strong honor code and ~75% shared curriculum across all majors help to promote collaborative, rather than competitive, work.

From the first semester, students engage in interdisciplinary, open-ended problems and projects, both individually and in teams. In keeping with training for future work in the real world, whatever it may be, courses also focus on teamwork, communication, and reflection and feedback as key skills engineers must possess. These courses provide students with multiple opportunities to practice and hone these skills. We estimate that Olin students have at least 32 project and teaming experiences of various duration before they graduate.

We use projects throughout the curriculum to emphasize the development of specific technical and professional skills. Overall, teams may be comprised of 2 to 6 students and projects may last from weeks to a

full semester. Students learn to address not only team dynamics, but also think about timelines, project planning, balancing workload, and participate in design reviews. Additionally, giving teams a high degree of autonomy in choosing topics and in guiding the direction of projects gives students a sense of ownership over and responsibility for the success of the project

Although students work on teams every semester, we explicitly lay a foundation for developing teaming skills in required courses that students take in their first two years. In these early experiences, we encourage students to focus on learning goals, as opposed to performance goals, as this has been shown to improve self-regulation and performance.[4] Students learn techniques for engaging in reflection about team roles and contributions and giving feedback. As they practice important team skills such as giving and using feedback to improve teaming interactions, students begin to understand the importance of explicitly addressing the functioning of the team and interpersonal dynamics in executing the engineering project. By the time they reach SCOPE in their senior year, students have internalized that these practices are an important component of project success and can readily put them in play. They are well prepared to solve team-dynamics issues on their own and can focus on the technical challengers of their projects (though faculty support is available for both).

A SCOPE team of 5-6 students works on a project for an entire year, their longest project of their academic careers. While there are 12-14 separate projects, SCOPE is envisioned as a single class with 12-14 sections to build a cohesive experience. The majority of Olin seniors take SCOPE (~70-75 each year), with a subset taking an alternative engineering capstone. Each SCOPE project has an industrial (or in some cases academic) sponsor, with a dedicated company liaison who is responsible for communication with the team. Each team also has a dedicated faculty advisor with whom they meet at least weekly, as well as technical 'angel' advisors with whom they consult as needed regarding technical challenges.

Projects are developed and chosen to align with student and faculty interests and expertise. More importantly, we seek to identify problems that the sponsoring companies have a concrete interest in ideally because of the potential of significant return from a new market or product. This class of projects results in high engagement from the liaison and in return, high engagement by students. Olin's lack of departments, degree of overlap in the curriculum, and emphasis on teamwork in many classes means that students are comfortable working on interdisciplinary teams. Because of this, we seek out projects that are quite interdisciplinary and as a result, more authentic in that they require a more holistic approach.

SCOPE has a number of internal deliverables including design reviews and project plans. Externally facing deliverables given to sponsors are a report and presentation at the end of the Fall and Spring semesters. Students also publicly present sponsor-approved presentations at an end of the year at SCOPE Expo day attended by various community members and interested industrial parties.

SCOPE is scheduled from 9am to 5pm on Wednesdays; students cannot take other classes during that time on Wednesday. This ensures that busy students (and faculty) have time to meet and work together, which has been shown to be an important aspect of supporting successful teams.[3] Shared Wednesday time also allows the offering of programmatic workshops on topics such as ethics, project planning, and feedback. Teams also present a series of design reviews.

Team Formation

Team formation begins at the start of the fall semester. The entire SCOPE class is given an overview of the projects available and given an opportunity to discuss the project further with faculty who are familiar with the project, and, in many cases, have been involved in developing the project with the sponsor. After this information session, students indicate their interest in and skills for each project in an online survey. Teams are formed using an iterative process previously described by Chang and Downey[5] that takes into account data from the student survey and also "soft data" including the knowledge faculty have about the requirements for each project and the characteristics of the students.

The survey asks students to score each project on a scale from 1-5, with 5 being a project they really want AND believe they have the skills for, 3 indicating willingness but not high preference AND/OR skills, and 1 indicating they don't want it AND/OR do not have relevant skills. Importantly, these scores are absolute, not relative; that is, students score each project independently, not in order of preference. A student might rate several projects 5, or might not give any project a 5. In addition to student preference, the teaming process takes into account GPA, student "antipreferences," citizenship requirements for each project, and information from the survey about what role students want to play on their teams. GPA is used as a proxy for both skill and work ethic, but it is supplemented with soft data from faculty. Our own experience with team formation is in line with reports from the literature that recommend distributing stronger and less strong students across teams.[3] Antipreferences allow each student to name up to 2 students they should not be teamed with because this would be detrimental to the functioning of the team; to their credit, students use

this option sparingly. With these inputs, we use a program, written and maintained by two of our faculty, to find allocations that satisfy all constraints and try to place all students on projects to which they gave high scores. The program generates a large number of possible allocations and keeps the top 20, according to a scoring function that quantifies the costs of violating student preferences or project requirements.

SCOPE faculty assess these allocations using their knowledge of project requirements and students' personalities and skills. These evaluations often reveal additional constraints, which we use to modify the allocation program and generate another round of allocations. As examples, we have the option to "lock" a student onto a particular project, bar a student from a project, or change minimum and maximum number of students assigned to any project.

Having refined this process over the past 9 years, we believe that the initial teaming approach contributes to the success of SCOPE teams. Initially, students voted on teams but team formation was done manually by SCOPE faculty. This process was time-consuming and resulted in student team allocations that were sometimes not well-matched with respect to skills and/or motivation. The semi-automated approach to teaming was introduced early after the second year and has evolved to be more efficient and effective.

We believe that there are a number of factors in our current approach that contribute to positive outcomes of SCOPE teams. First, students get a choice in selecting their project. In our experience, all but a few students are placed on a team they rated 4 or 5, with approximately 3 students per year on teams they rated 3. We have never been forced to supercede a student's stated teammate anti-preference. Second, because the process is at least partially automated, students and faculty feel that it is fair and rational. Lastly, this process tends to distribute students across teams in a way that matches student skills with project requirements. Because of these factors, we believe, long term motivation and satisfaction seem to be quite high.

What Makes Teams Successful?

In addition to focusing on a satisfactory initial team formation, there are a number of other features of SCOPE that we believe support healthy teams and promote their success. In particular, teams have a great deal of autonomy which gives them ownership over the project. Student teams feel direct responsibility for their work. Faculty advisors act more as mentors or coaches rather than as the project leader. Importantly, teams are responsible for initiating and engaging in weekly direct communications with the sponsor liaison. Faculty periodically check in with the liaison to make sure communication with the team is effective and that the sponsor is satisfied with the team's progress.

There are a number of specific roles on each team, some of which are externally facing and some of which deal with internal operation. Each team has a Project Manager who is responsible for team organization. They are the point-person for liaison communications. They may meet with faculty advisors outside of team meeting time to discuss team management.

Teams are also given responsibility for managing their own budget. A member of the team, designated the Business Manager, after attending budget trainings, work with their faculty advisor and the SCOPE staff to develop an approved budget. They are issued an Olin credit card to make purchases for the team and have the freedom to purchase items of low to moderate cost on their own.

Other internal team roles are Communications Manager and Safety and Ethics Lead. The Communications Manager is responsible for navigating non-disclosure agreements and getting sponsor approval for and submitting photographs and written material that can be used in SCOPE publicity. The Safety and Ethics Lead is responsible for working with Olin safety staff to identify any safety issues associated with the project and developing appropriate procedures or acquiring training and protective equipment. They are also responsible for leading the team in a discussion of any ethical concerns with the operations of the project.

On a practical level, teams are given a dedicated space to meet and work. They also have their own phone and dedicated desktop computers (as needed). Additionally, in order to build community, teams are grouped within a few rooms, most of them located close to each other.

Feedback

As previously described, students learn and practice feedback and team-improvement skills throughout the curriculum prior to enrollment in SCOPE. Two key skills are reflection and feedback. These are promoted in several ways in SCOPE. First, every other design review is designated a Process Review. In these, we ask students to report on where they are in their project, using a graphically informative time line. We also ask them to reflect on their process, both as a team and also with respect to their overall project. The prompt is left intentionally ambiguous to both recognize that these are interrelated and also that the teams have different needs at different times. Teams are asked to discuss and identify what is working well and what needs improvement. Doing this in a design review format means that they are held publicly accountable and can get feedback from the team they are paired with, faculty advisors, and angel advisors.

Additionally, twice per semester, students are issued

a peer- and self-assessment survey that is submitted to their faculty advisor. Students are asked to assess both themselves and their teammates. The format of the survey has evolved over time and most recently asks 4 questions on a Likert scale, derived from the CATME teamwork survey,[6] that focus on 1) the quality of each individual's contributions, 2) positive interactions, attitude, and communications and responsiveness to feedback, 3) efforts to keep the team on track, and 4) demonstration of or willingness to acquire the knowledge and skills to do excellent work. Additionally there are open-ended questions asking them to reflect on individuals' strengths ("I like….") and areas for improvement ("I wish…") as well as feedback for their faculty advisor.

Faculty use this information to generate both formative and summative feedback to the students about their performance. We also encourage teams to implement this type of feedback internally over a shorter time scale, and many teams do. In the best case scenario, the feedback from the faculty advisor is redundant because the students have heard it directly from their teammates. However, this system allows faculty and the program to keep records of student feedback and pushes teams who do not implement internal feedback to give feedback. In the case of a poorly functioning team or teammate, it also provides another mechanism for students who have a hard time giving direct feedback to provide it more anonymously to their faculty advisor. Our experience is in line with others' observations that peer feedback is a major driver in improving team performance.[3]

Summary and Implications

In end of the course surveys, SCOPE students highlight teamwork and team dynamics as the most important factor in determining whether their SCOPE experience did or did not go well. They rank this above the project they were on, sponsor relations, and learning objectives. Students' own observations support our belief that it is important to focus on actively fostering and supporting teams as they work on the largest, longest project of their careers to date and as they prepare to enter the workforce or attend graduate school.

In short, the team experience is key to project success (in the eyes of students and sponsors) and student satisfaction. Further, teamwork is something that must be practiced.[3] As such, we believe that the success of SCOPE is due to the extensive experience working on teams that Olin students gain in the rest of the curriculum. An orientation towards collaboration, process, and peer-to-peer learning, versus a more disconnected task-oriented approach, leads to better experiences and learning outcomes for team members.[2,3] While it may take a lifetime to perfect teamwork skills, our students have an excellent foundation and can avoid some of the team dynamics problems that can derail work on a technical problem. In Olin's spirit of continuous improvement, we continue to strive to find ways to help students develop as team members to maximize their experience and improve project outcomes for sponsors.

While it is difficult to make comparisons between outcomes for SCOPE students at Olin and capstone students from other colleges or universities, we can examine some of the practices we have engaged in through the lens of research on teamwork. Certainly, the tight-knit, collaborative culture at Olin is somewhat unique to engineering schools and likely plays a role in influencing positive team dynamics.[7] However, many of the activities students engage in can be cultivated elsewhere. For example, it has been reported that factors such as explicit faculty discussion about teamwork, focusing on the organization of the team, and giving and receiving peer feedback throughout the semester result in more successful teams.[1] Moreover, successful teams have been shown to actively engage in fostering communication while poor communication leads to ineffective decision making, negative influences on team member self-efficacy, and poor project outcomes.[1,7]

The implications of this discussion are not surprising – teamwork is important for the successful execution of projects. We hear this message from industry continuously. And yet, we often consider it one of the "soft" skills to be picked up alongside the "hard" technical skills engineering students are learning. This is a reminder that these skills are incredibly important if we want our students to succeed and that expecting them to just pick them up in the senior year is too late. They need to be taught throughout the curriculum.

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