Revising Roles: Enhancing an Engineering Capstone Course to Improve Outcomes for Women

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Abstract

Women leave the engineering profession at a high rate, and this attrition is observed both in the university setting and in the workforce. Female students cite negative experiences with peers as a major contributor to their dissatisfaction with engineering. Many of these negative experiences occur in team projects that are ubiquitous in engineering programs. In the absence of intentional instruction on teamwork and effective collaboration methods, students—especially women—struggle and have negative experiences that stymie the self-efficacy and confidence-building that should occur during the senior year. The objective of this paper is to highlight key issues with engineering capstone projects and to identify best practices that result in better outcomes for women. This work evolved from the first author's experience in teaching the civil engineering capstone course and from participating in a "Writing in the Disciplines" group, led by the second author. The group provided a forum for brainstorming ideas and the course provided a platform for testing these strategies. Four recommendations evolved from this effort: 1.) Education on team function and bias in team dynamics is helpful. 2.) Teamwork skills and strategies for collaboration and conflict resolution need to be taught. 3.) Mentoring and engaging with students is an important aspect of the process and can be enhanced to better serve women. 4.) Reflection and self-assessment exercises can be integrated to build self-efficacy and confidence in students. Assessment was done using data collected from mid-term evaluations, peer evaluations, self-assessment exercises, input from industry judges, and teaching evaluations. The major outcome of this study was that instructors can make reasonable modifications to team projects to better serve women. Likewise, students can develop skills that improve their ability to function on teams, leading to better capstone experiences and improved self-efficacy as they enter the engineering workforce.

Introduction

While women have made significant gains in many professions over the last century, women continue to have less participation in engineering. This consistent underrepresentation [1, 2] appears to exist for two reasons: Women enter the discipline at lower rates than men and leave at a higher rate [1-3]. Specifically, during the time period 2000-2015, women earned 20% of engineering bachelor's degrees but represented only 10-15% of the engineering workforce [2]. Such statistics are a concern not exclusively for reasons pertaining to gender equity but also to issues related to the future of the field as well. Those who have investigated the value of diversity in STEM professions identify an "'innovation dividend' that leads to smarter, more creative teams, hence opening the door to new discoveries" [4; p 1740]. However, most acknowledge that greater diversity necessitates higher-levels of team participation from *all* members if those innovation dividends are to be realized [5].

Although there are various causative factors for the lower participation of women in engineering [1], in one large-scale study, professional women cited workplace climate as one of the most common reasons for leaving the field [3]. In the university setting, negative experiences during internships and co-ops as well as negative experiences with peers have been identified as contributing factors for women reconsidering engineering [6]. Specifically, female students often report negative experiences in team projects such as being subjected to stereotypes and assigned

gendered roles [6-8]. For example, in one controlled study researchers found that female students were delegated less important tasks, spoke less in presentations, answered fewer questions, and were more likely to be assigned interpersonal and relational tasks while men were assigned goal-oriented tasks [7]. In Meadows and Sekaquaptewa [7], role assignment was important because male students tended to take on tasks (speaking, leading, decision-making) that are correlated with active learning and development of self-confidence.

Background: Capstone Courses and Projects

Negative experiences of female students in team projects is especially troubling because teamwork is ubiquitous in the engineering curriculum and in the workplace [9]. The engineering capstone design project—that students complete in teams during their senior year of the undergraduate program—is valued by faculty, industry, and the accreditation board (ABET) [10]. In the capstone course, students work on real-world projects that cause them to rely on previous knowledge and coursework and to build mastery in their chosen discipline [11, 12]. The realistic problems give students experience working with multiple constraints such as time limitations, budget, safety, sustainability, and client needs. In the capstone course students are advised by faculty and often by industry advisers and/or sponsors [10, 13]. Thus, the capstone course is intended to help students prepare for the workforce and develop self-efficacy in their profession [9].

Given the importance of the engineering capstone project and the documented negative experiences that female students often have in such projects [6-8, 14], developing best practices for team-based learning in engineering is important to encourage women to persist. Thus, our goal was not just to explore best practices for engineering capstone course design but also to identify ways of cultivating inter-personal communication skills that would improve the experiences of women working on design teams. Inherent in this endeavor is the belief that inter-personal communication and other "soft skills" can be taught, a perspective shared by others, such as those working to foster empathy in engineering courses [15].

Capstone course structure

The first author is a civil engineering faculty member at the University of the Pacific where the civil engineering capstone course is completed in one semester during the senior year, usually following the mandatory co-op experience. Students work in teams and take on one of the following roles: structural designer, geotechnical designer, water resources designer, or environmental designer. Each team has a project manager, team name, and a logo. The course is assigned an instructor although students are advised by all department faculty on different aspects of the project. There are also industry advisor(s) and/or a project sponsor. Students often find their projects and industry advisors while they are completing the co-op experience. Sometimes engineers within the community volunteer their time as advisors and bring their own projects. Other typical projects involve design of a new campus building or development of an empty property lot within the city. Similar to what is done at other institutions, students interact with local engineers, stakeholders, and city officials during their projects [13, 16]. Each team works on a unique project.

The course has been improved over the years—as different faculty teach the course and collaborate on the course content—and is structured to promote continuous project progress. At the beginning of the semester, teams write a proposal and deliver an oral presentation to faculty

and their peers. The proposal contains a scope of work, breakdown of hours anticipated, and a Gantt chart schedule. After the proposed project is approved, the instructing faculty member meets weekly with the teams to discuss progress. Time sheets are kept by each student and the expected contribution over the semester is 180 hours (for a four unit course). The teams maintain blogs that are updated weekly with progress reports. Mid-semester, progress presentations are given where faculty provide feedback on the works in progress. The final products are a project report, a presentation delivered to a panel of industry advisors (who serve as judges), and a poster session following the presentations. The projects are rated by the industry advisors and a winning team is selected based on the scores. Thus, student team products are assessed by an outside, neutral "control" evaluator, and not just the course instructor.

In addition to structuring the course to promote progress, faculty integrate course elements to promote team function. Self-selection of teams is typically done. The teams select a project manager. Teamwork is discussed during the first class meeting and the teams develop written rules in class or shortly thereafter. Peer evaluations are collected three times during the semester: after completion of the proposal, after the progress presentation, and at the end of the term. A student can be removed from a team and/or from the class if the student is not performing satisfactorily. Situations that warrant dismissal include not turning in work on time, not contributing to collaborative assignments, not attending team meetings, and not communicating with team members. Student progress is evaluated during the weekly meetings and assessed based on information from the peer evaluations. Student removal from teams is rarely done.

The structure of our capstone course appears typical of what is used at other institutions [10-13]. The teams are usually comprised of four students, which is consistent with recommendations for team size in an engineering setting [17]. While instructor selection of teams is advised by some [12, 17], most of our faculty allow students to select their teams to give students autonomy over their groups, making them feel invested in these teams (rather than feeling stuck with what they were assigned). The use of weekly meetings and peer evaluations is aligned with the practices of other institutions [18]. Time sheets are also used by others [13]. Although the structure of our course appears consistent with common practice, we are likely able to interact more closely with the students as a result of our small size and high faculty-to-student ratio.

The literature contains interesting discussions on some apparent conflict between faculty teaching capstone courses regarding the evaluation of the students' work on these project, with some placing higher value on the final product produced by the students rather than the process that students undertake to achieve such a product [10-12]. Although our faculty likely fall on different places in the process-product spectrum, our program clearly values both process and product. The rubrics for the final report, presentation, and poster emphasize the final product while we also have many intermediate assignments aimed at developing the design process. Within the literature there is a similar discussion on the relative weighting of technical skill development versus professional skill cultivation [12]. Here again, we try to balance development of these two types of skill sets, fostering both.

Challenges in capstone courses

Despite our use of best practices in the capstone course, it is a challenging course for both students and faculty. Compared with other courses, it is a "high stakes" proposition because the

students are being evaluated by all faculty and by a panel of industry advisers. Unlike most engineering courses, the content is student-driven and unstructured compared with the homework-exam paradigm used in most other engineering coursework. Also, unlike most engineering courses, the projects posed are "wicked problems" that can be approached in different ways with potentially different outcomes. The capstone course causes students to rely on previous coursework that they may not recall well (e.g., drafting and surveying) in addition to relying on sources of information with which they are not familiar (e.g., building codes, manufacturer's data sheets, master plans). In short, in our capstone course there are many deliverables that the students struggle to manage, especially since they may have other challenging coursework, and many are holding part-time jobs (e.g., with their co-op employers). Probably the most challenging part of the project is that it is done collaboratively in a team. While we do incorporate teamwork in previous coursework (e.g., lab reports), none of the previous experiences are as intensive as in the capstone course. Some students struggle with time management and procrastination, and these deficiencies can become a problem for the entire team.

Improving (Women's) Experience in Capstone Courses

Given the documented negative experiences of women in engineering team projects, the first author became interested in how to improve the experiences of women. She did not have any evidence to suggest that the women in her civil engineering program were having negative experiences, and perhaps the fact that this was never investigated is symptomatic of the problem. However, she did notice anecdotally that women appeared under-represented in the capstone project winning teams over the 10 years that she has served as a faculty member. Serendipitously, as she was pondering this issue, she joined an inter-disciplinary faculty learning community led by the second author that focused on using writing across the curriculum to improve student thinking – to use iterative revision to refine ideas, to encourage reflection and metacognition, as well as to develop communication skills. The monthly meetings with this faculty group gave her a space for dialogue on emergent concerns and a wealth of wisdom to draw on from other fields in "real time," as her capstone course unfolded.

This study is based on observations made over two years of teaching the civil engineering capstone course (2018 and 2019). Sixteen students were enrolled in the course each semester and were divided into four design teams with four students in each team. Surprisingly, each class had the same gender breakdown: eight men and eight women. The team gender breakdown was also the same in both classes: one team had all women, one team had two women and two men, and two teams had only one woman. Given this gender breakdown and the demographic similarities in the two classes, it was possible to observe different dynamics in the teams over two years in a way that more reliably allowed the authors to see patterns, draw conclusions, as well as refine and recommend practices. Further, the course already had an unbiased mechanism for noting improvements for women in the form of the external project evaluators.

When the first author started teaching the capstone course she felt that the existing framework was good and did not intend to completely disrupt it. Based on the work of Seron et al. [6] and Oakley et al. [17], however, she wanted to review and validate the pre-existing frameworks and make modifications that would serve all students better. The structural pieces of the capstone course are important; however, based on the literature it seems unlikely that employing a good structure is sufficient to address inequities experienced by women [1, 6, 8, 14]. At the outset, the

ideas for improving the senior design experience were as follows:

1. Educate students about team function and bias and inequity on teams to improve awareness and to develop strategies to reduce it.
2. Teach tools for interpersonal communication to improve team members' abilities to independently solve problems.
3. Mentor and engage with students to provide reassurance of their development as engineers.
4. Build in reflection and self-assessment exercises to increase team function and team members' engagement and satisfaction with the team and project and with self-efficacy.

The first author used previously adapted structures as well as the framework presented by Oakley et al. [17], with modifications, in ways that she thought best met the needs of the students. Many of the recommendations made by Oakley et al. [17] were already in use in the civil engineering capstone design course: team rules, preliminary instruction on teamwork, and a policy for removing poorly functioning students from teams. Changes made to the existing capstone course using suggestions from Oakley et al. [17] were: a policy statement written by the instructor and distribution of a "Coping with Hitchhikers and Couch Potatoes on Teams" reading that provides strategies for dealing with problems on teams. The additional changes, how they were implemented, and how they served students are discussed in more detail below. Evaluative data that informed the impact of her interventions were collected in the forms of mid-term evaluations, peer evaluations, self-assessment reflection exercise, input from judges, and teaching evaluations.

Intervention 1: Educate students about team function and bias on teams

Instruction on team function and malfunction. One of our underlying beliefs is that students in general (and women specifically) will not be successful in team projects if they do not know how to function on a team. Further, teamwork is not always intuitive. However, teamwork can be taught, or at least tools for more effective teamwork can be taught, and team members can develop awareness of issues in teamwork [14, 19]. Teamwork can also be learned over a long period of time, following much trial and error, and this is likely how many people learn how to function on a team. Given that the first author did not have the luxury of lots of time in her capstone course, effective and ineffective teamwork was discussed on the first day of class with some basic instructions and recommendations.

Hitchhikers and couch potatoes. Following the advice of Oakley et al. [17], the first author distributed a handout describing "hitchhikers"—who intentionally get out of doing work to the point of being deceitful and manipulative—as well as "couch potatoes" who are lazy and exhibit bad study habits (e.g., procrastination). One of the benefits of the handout was that it gave common terminology for discussing the problem of dysfunctional team members throughout the semester, and contributed to the development of "scripts" that the students could use to engage in conflict resolution. After distributing the handout, there was a marked difference in student attitudes. Towards the end of the semester, one student disclosed that the handout influenced his behavior in the class in that he realized that he had acted as a couch potato in the past and needed to "clean up" his behavior.

Disproportionate workloads for women. It is especially important to be transparent and discuss

poor teamwork in class because we suspect women suffer more from these negative behaviors on teams. Some of the poor teamwork is evident in the hitchhiker and couch potato behavior, but there are other gender-associated negative team experiences as well. We have observed women students disproportionately "picking up the slack" when other students are not performing and doing more than their fair share of the collaborative parts of the project (especially writing tasks). This is documented in the literature as well. Women doing more than their fair share of the work on a team was reported by Ingram and Parker [8] where lack of initiative led to a solo women on a team doing most of the work. Women taking on a disproportionate part of the writing tasks was reported by Meadows and Sekaquatewa [7] where male team members took on more of the technical tasks. Tonso [14] and Mallette and Ackler [20] also reported work imbalance on teams where women's contributions—especially in writing assignments—were not adequately acknowledged. We believe this disproportionate workload is often achieved by male team members using false-praise-attribution—a phenomenon heretofore not discussed in the literature on teamwork—where males claim "she has neater handwriting" or "she is a better writer than I am," as if this (even if true) justifies asking women to do more of the work. And unfortunately, unless this phenomenon is called out at the outset, too often women initially accept the "compliment" and end up later resenting their male colleagues. Some of this disproportionate workload may also be the result of academic malalignment where different students have different ideas about timely submission of work and the quality of the work, especially in submission of reports and presentations [8, 21]. Academic malalignment causes students to have different values and to approach the capstone project differently. Again, women seem to fare poorly in these situations and take on a disproportionate share of the workload.

No voice and self-blame. Another area where we observed gender bias was in whether female team members felt able to contribute equitably and "have a voice" within the team. In reviewing submissions from the self-assessment writing assignments, we observed 25% of the women identifying that they did not feel like they had equal participation and "say" in the team discussions and decisions. These women also self-blamed, feeling that they just needed to speak up and be more assertive, as opposed to faulting other team members or team structure issues. Their feeling of exclusion was related to reluctance to engage in conflict within the team. Such hesitancy to engage in team discussions and decisions was also reported by Ingram and Parker [8] where a lone women on a team of four was consistently passive. Meadows and Sekaquaptewa [7] also reported a lack of engagement by women team members, including a case where a male team member commented on his female partner's ability to be quiet and follow direction.

Team rules. By acknowledging some of the problems inherent in teamwork early in the semester, the teams were better prepared to write team rules. By the end of week of week two, each team was instructed to submit its own agreements, addressing the following issues:

- Team expectations of behavior
- Plans for communication and file management systems
- Meeting time and place
- Plan for contingencies (e.g. due to uneven workload)
- Steps for conflict resolution

Mid-semester the teams reviewed their rules and revised them as necessary. The first author intentionally waited until the students had some experience working on teams before asking

them to refine their practice. It was hoped that this strategy would increase student agency and buy-in. Through classroom discussion on teamwork, reflection, and individualized support on resolving problems, revisions to team agreements could emerge more organically. In 2019 most teams felt that their rules were functioning well and did not require revision, but even without making any changes this exercise gave them the opportunity to review and revisit these rules. Therefore, this activity not only served as a way of checking in on group function, but also emphasized the value of revision as both a tool for improvement and a tool for reflection. Indeed, weaving iterative conversations about team function throughout the semester signaled that team health-maintenance requires regular attention.

Instructor policy statement. In addition to having teams write their own rules, at the beginning of the spring 2019 semester The first author also wrote a policy statement based on recommendations of Oakley et al. (2004). In the policy statement, she communicated her values for teamwork and her expectations. She also stated that in addition to their meeting with her, she expected student teams to meet with each other weekly, which they had not always done in the past but had always been an assumed aspect of the class. Problems with student meetings, including both frequency and content, has been reported by others [18]. Thus, writing out the expectation that students meet together outside of class made explicit what had heretofore been implicit. The first author also wrote detailed procedures for removing students from teams in the policy statement. The procedure consisted of a step-by-step guide to supplement the retention policy already contained in the syllabus. Providing this policy statement communicated to students that the instructor was knowledgeable about group function and could be a trusted guide to students going through an unfamiliar process.

Transparency about problems for women on teams. Mid-semester the first author delivered a short presentation to the students with data on attrition of female students in engineering and with evidence from Seron et al. [6] on the negative experiences of women in engineering programs. Some of the students seemed surprised by the data presented. Some students even questioned the quality of these data. Other students were resigned to these facts and unsurprised. However, for many women these data seemed to provide validation that they needed to be more assertive on their teams. Having a class discussion on equity contributed to the shared language and the ability to engage in dialogue about such issues.

Intervention 2: Teaching tools for interpersonal communication

As mentioned previously, following best practice recommendations for group structures and processes is not enough to weed out systemic inequity. Indeed, probably the most important lesson the first author learned from teaching the capstone course and reflecting on that experience is that students need to learn interpersonal communication skills. Students need scripts for addressing conflict with their peers. Engineering students are often highly conflict adverse, especially if they feel marginalized in a group. They would rather ignore conflict and just endure unfavorable situations until the end of the semester when the whole thing is over. Or, they would like to complain bitterly without having to resolve their issues. This aversion to conflict is troubling because the problems that students face in the capstone course are likely the same problems that they will face in the workforce. We believe that a reluctance to deal with conflict may prevent women from having a larger role in the engineering profession. We also suspect that the "false-praise trap" discussed previously leads women to self-blame. When male team members use flattery to get women to do more work (e.g., "you are so much better a writer

than I am, you should draft the report"), women may initially get lured by the praise. Only later when they realize they are stuck with extra work do they feel angry, but they stew in silence because they feel they brought it on themselves by falling into the trap.

Individual consultations. Fortunately, by inviting opportunities to address conflicts and model effective defusing strategies, an instructor can provide ways of addressing resentment and teach valuable life-skills lessons. The main mechanism used for discovering conflict in teams were the written peer evaluations that occurred twice during the semester (and a third time at the semester's end). After receiving and reviewing the peer evaluations, students were invited to come and meet with the instructor individually to discuss how to address their dissatisfaction with the team dynamics. During the meetings they discussed the situation and strategized how the student could better deal with and mitigate the negative team situation. The first author felt that these meetings were especially productive and useful because they were confidential and specific to the individual's unique situation.

However, one challenge faced is that students can be non-responsive to invitations to meet and discuss the negative team behavior that they have reported in their writing. Some students insist on anonymity that also can prevent addressing problems within teams, avoiding a potential growth opportunity for the students. Sadly, the students who are often the most resistant to addressing conflict are the ones with minor problems that could be easily solved. This lack of commitment to problem-solving impacts students because they don't build problem-solving skills. It is better for students to work on addressing small problems, and gain practice, so that they are proficient at addressing conflict when bigger problems arise. One approach to deal with non-responsiveness on peer evaluations in the future would be to clearly outline in the policy statement the methodology for responding to peer evaluations. Also, it is important to not rely on only one strategy for addressing these issues. Table 1 contains a list of common problems encountered in the teams and suggested scripts for how students might deal with such issues—this list is intended to provide a starting point for students dealing with conflict on teams.

Non-Violent Communication Techniques. To further address the lack of conflict resolution skills in students, the first author also introduced Non-Violent Communication (NVC) as a methodology and a script for addressing and resolving problems in teams [22]. In NVC, a person first observes a situation, states how they feel about it, makes clear what their needs are, and then makes a request [22]. The NVC concept was introduced in class—mid-way through the semester—and the students practiced using it by developing and resolving a hypothetical situation. Oakley et al. [17] also has students practice conflict resolution in "crisis clinics" where they brainstorm mitigation strategies for hypothetical situations although specific communication techniques are not recommended. The point being: Interpersonal communication methods and conflict resolution techniques are useful and students need opportunities to practice them.

Intervention 3: Mentoring and engaging with students

Mentoring has been identified as a critical factor in engineering capstone courses [9, 11, 12]. While mentoring occurred during class and individual meetings with students, probably the most significant mentoring in the capstone course occurred during the weekly team meetings. The main purpose of the meetings was to make sure that each student was progressing sufficiently in their individual work. During the meetings, each team member presents work in progress—relaying information on problems encountered, especially those that may delay progress—and

describes which tasks they plan to do next. The students also discuss progress on collaborative work such as reporting and presentations.

In addition to checking on student progress during the weekly meetings, the first author structured the meetings to encourage mentoring. To model good practice, she sent an agenda via email two days in advance to help the students arrive prepared. The first line item on the agenda was always a check-in with students to provide "open space" for whatever the students want to discuss. Some teams responded with a "we're fine" while other teams wanted to discuss how many exams they had, health status (e.g. illness), how many hours of sleep they were getting, etc. This agenda item served to "clear the air" and seemed to help students "get things off of their chest" before getting into the details of the meeting. The first author also added line items on the agenda about upcoming deadlines and workload distribution to get them thinking about who worked hard on previous assignments and who should be given more responsibility on upcoming assignments. Intentionally putting this on the agenda communicated to the students that their instructor valued equitable workload distribution and collaboration.

Based on evidence provided by Seron et al. [6], it is clear that female students benefit from engaging with faculty and getting reassurance from faculty. The first author's meetings with the students were structured to provide this type of reassurance—she listened to them describe the work that they are doing and provided guidance on how to proceed. In one meeting she asked the students what they were doing to become experts. The following are some of the responses received:

- seeking advice from different types of people (faculty, industry mentors, sales people)
- reading different sources of information from the "Cliff notes" to more in-depth sources
- learning about background information (history of a region, biological resources)
- trial and error designing (learning by failure)
- figuring out how things are done in practice
- examining manufacturer's information
- considering alternatives and learning about the options not selected in order to defend design choices
- connecting the design work to previous coursework (e.g., load pathways in structures)
- recognizing design features (e.g., stormwater drainage systems) in daily life

Discussion on how one becomes an expert became an important theme in the second year of teaching the capstone course. It was clear that developing confidence and independence was an important part of their experience, and being able to reflect on this development became an important part of the weekly meeting. It was noted by several faculty that students were becoming too reliant on their industry mentors, and the weekly meeting was an opportunity to enforce good practices and development of self-reliance.

Intervention 4: Building in reflection and self-assessment exercises

The capstone course provided opportunities for reflection and self-assessment that build self-efficacy in students. These were pitched as essential professional habits that students should begin practicing as soon as possible. This past year the first author had students complete an in-class "assess and adjust" exercise after Spring Break where they reflected on their performance and the performance of their team [23]. They then brainstormed ideas for improving both their

own function in the course and the function of their teams. There were in-class writing exercises on independent learning and ethics, and these exercises provided further opportunities for reflection and self-awareness. In the independent learning module, students wrote narratives about their career and personal plans, their experiences in the class, and independent learning that they needed to do to meet their long-term goals. In the ethics module they were asked to reflect on ethical and professional behavior and how that behavior influenced their capstone experience.

Similar to the "assess and adjust" exercise, as mentioned previously, the first author conducted mid-term evaluations where she asked students about problems in their teams and in the course [23]. She then consolidated and made the responses anonymous so that she could report back to the students, using the aggregated information. What she learned in the first year of teaching the course was that there were a lot of problems centered on the team meetings. Similar problems have been noted in other publications [8, 18]. A common problem was that students were not going to the team meetings or were arriving late. The students noted other problems with meetings such as trouble staying on task, lack of organization during meetings, and meetings that were too long. Other team problems noted were regarding the file management and communication systems that the teams had implemented. Not surprisingly, there were a lot of problems reported on the distribution and completion of work tasks. Students noted problems with members working on the wrong tasks, schedule/deadlines that were insufficient, time management issues, uneven workload, procrastination, and students struggling to work well independently. The failure to come to consensus was also noted. In both years that the first author taught the course, women complained that their voices were not being heard. To address the lack of voice on teams, the first author conducted an open class discussion about how all students could better listen to all team members. This discussion raised awareness of the issue, even for those who might not have mentioned it or experienced it previously. The students had various ideas regarding solutions, and the one that stood out was simply having "open space" during meetings to allow everyone the opportunity to speak and have their concerns expressed. This activity was yet another way of supporting not just women on the teams but every student whose voice was being shut out.

Communication feedback loops. In the reflection exercises, the first author was able to learn from the students and responsively create a feedback loop. For example, from the mid-term evaluation she learned that students need more guidance on running team meetings. To provide guidance on running meetings, she held class discussion and started modeling good meeting conduct in our weekly meetings (email notifications, agenda distributed in advance, staying on task). To deal with workload issues, she started putting this item on the weekly meeting agenda so that we could discuss it openly. To deal with students struggling to work independently and work on "wicked problems," she has had students reflect on independent learning and commit to self-reflection. While these activities do not make the course easy, it does appear (based on teaching evaluations) that the students have a better experience and that better products are produced as well (based on input from the industry judges).

Results and Conclusion

Building intentional activities into engineering capstone courses can improve the teamwork experience for female students, and potentially for all students. Our vision for students in the capstone course is to feel confident and accomplished at the end of the semester and to have a

product they can be proud of. The capstone course is important in developing effective teamwork skills that can carry over professionally. While it is difficult to measure success in making the capstone course more supportive of women—especially given our small institutional size—we can report that there are more women on winning teams since the first author has begun these interventions. In fact, in the past two years running, the external panel of judges chose all-women design teams, and provided positive feedback on both the projects and the team performance, lauding team cohesiveness and communication skill. While this result might suggest that same-gender teams benefit women in engineering capstone courses, the data presented here—limited by the department size—suggests that gender composition of engineering capstone teams warrants further study. It would be useful for faculty of capstone courses to have better information on optimal gender distribution and common problems associated with different gender compositions.

In the end, it is important to follow good practices for instructing a capstone course (e.g., intermediate deadlines, regular meetings). These practices are well-described in the literature. Given that there is evidence that women still have negative experiences in teamwork, in addition to following these best practices, we recommend specifically implementing activities to improve the experiences of women and other students from historically marginalized groups. These activities specifically involve the use of language: handouts to provide shared terminology, written team agreements to increase member accountability, NVC to develop a script for interpersonal communication, and written reflections to encourage metacognition and to capture feelings in real-time. Thus, language creates a set of expectations that can shape subsequent behavior. Further, educating students on team function and bias in teams builds awareness and better strategies for dealing with team malfunction. Teaching interpersonal communication tools to help students to learn how to resolve their own conflicts. Mentoring and engaging with students can provide support and modeling to develop self-efficacy. Finally, reflection and self-assessment exercises further build self-efficacy and autonomy in students by helping them to see themselves as good team members and as good engineers.

References

[1] C. Corbett and C. Hill, *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington, D.C.: American Association of University Women (AAUW), 2015.

[2] NSB, "Science & Engineering Indicators 2018," National Science Board (NSB), National Science Foundation (NSB-2018-1), Arlington, VA2018.

[3] N. A. Fouad and R. Singh, "Stemming the Tide: Why Women Leave Engineering," 2011.

[4] M. W. Nielsen, S. Alegria, L. Börjeson, H. Etzkowitz, H. J. Falk-Krzesinski, A. Joshi, E. Leahey, L. Smith-Doerr, A. W. Woolley, and L. Schiebinger, "Opinion: Gender diversity leads to better science," *Proceedings of the National Academy of Sciences,* vol. 114, pp. 1740-1742, 2017.

[5] C. K. De Dreu and M. A. West, "Minority dissent and team innovation: The importance of participation in decision making," *Journal of Applied Psychology,* vol. 86, pp. 1191-201, 2001.

[6] C. Seron, S. S. Silbey, E. Cech, and B. Rubineau, "Persistence is cultural: Professional socialization and the reproduction of sex segregation," *Work and Occupations,* vol. 43, pp. 178-214, 2016.

[7] L. A. Meadows and D. Sekaquaptewa, "The influence of gender stereotypes on role adoption in student teams," in *120th ASEE Annual Conference & Exposition*, Atlanta, GA, 2013.

[8] S. Ingram and A. Parker, "Gender and Modes of Collaboration in an Engineering Classroom:A Profile of Two Women on Student Teams," *Journal of Business and Technical Communication,* vol. 16, pp. 33-68, 2002.

[9] R. Konrad, A. Hall-Phillips, and A. R. Vila-Parrish, "Are Our Students Prepared? The Impact of Capstone Design Pedagogical Approaches on Student Skill Development During Industry-Sponsored Fieldwork," *INFORMS Transactions on Education,* vol. 18, pp. 183-193, 2018.

[10] J. J. Pembridge and M. C. Paretti, "Characterizing capstone design teaching: A functional taxonomy," *Journal of Engineering Education,* vol. 0, pp. 1-23, 2019.

[11] Z. Zhou and P. Pazos, "Managing engineering capstone design teams: A review of critical issues and success factors," in *2014 Industrial and Systems Engineering Research Conference*, 2014, pp. 3006-3011.

[12] M. Paretti, R. Layton, S. Laguette, and G. Speegle, "Managing and mentoring capstone design teams: Considerations and practices for faculty," *International Journal of Engineering Education,* vol. 27, pp. 1192-1205, 2011.

[13] B. E. Barry, V. P. Drnevich, A. Irfanoglu, and D. Bullock, "Summary of developments in the civil engineering capstone course at Purdue University," *Journal of Professional Issues in Engineering Education and Practice,* vol. 138, pp. 95-98, Jan 2012.

[14] K. L. Tonso, "Teams that Work: Campus Culture, Engineer Identity, and Social Interactions," *Journal of Engineering Education,* vol. 95, pp. 25-37, 2006.

[15] J. Walther, S. E. Miller, N. W. Sochacka, and M. A. Brewer, "Fostering empathy in an undergraduate mechanical engineering course," in *American Society for Enginieering Education (ASEE) 123rd Annual Conferecne and Exposition*, New Orleans, LA, 2016.

[16] K. A. Mazurek and G. J. Putz, "Discussion of "Summary of developments in the civil engineering capstone course at Purdue University" by Brock E. Barry, Vincent P. Drnevich, Ayhan Irfanoglu, and Darcy Bullock," *Journal of Professional Issues in Engineering Education and Practice,* vol. 138, pp. 314-314, Oct 2012.

[17] B. Oakley, R. Brent, R. M. Felder, and I. Elhajj, "Turning student groups into effective teams," *Journal of Student Centered Learning,* vol. 2, pp. 9-34, 2004.

[18] G. K. Watkins, "Best practices for faculty mentorship of capstone design projects," in *Proceedings of the 2011 ASEE Annual Conference & Exposition*, 2011.

[19] C. R. Haller, V. J. Gallagher, T. L. Weldon, and R. M. Felder, "Dynamics of peer education in cooperative learning workshops," *Journal of Engineering Education,* pp. 285-293, 2000.

[20] J. C. Mallette and H. Ackler, "Valuing women's contributions: Team projects and collaborative writing," presented at the 2018 ASEE Annual Conference & Exposition, Salt Lake City, Utah, 2018.

[21] V. Pieterse and L. Thompson, "Academic alignment to reduce the presence of 'social loafers' and 'diligent Isolates' in student teams," *Teaching in Higher Education,* vol. 15, pp. 355-367, 2010.

[22] CNVC. (2019, June 14, 2019). *The Center for Non-Violent Communication*. Available: https://www.cnvc.org/

[23] K. A. Rockquemore. (2010, March 8, 2010) Time for a 360. *Inside Higher Ed*. Available: https://www.insidehighered.com/advice/2010/03/08/time-360

Table 1. Problems that occur in student team projects and recommended actions and scripts for conflict resolution.

Team malfunction can occur when team members do not:	Recommended actions and scripts for conflict resolution
Meet internal deadlines	Clarify expectations by putting internal deadlines in writing (e.g., in the meeting agendas). Send reminders of upcoming deadlines (e.g., "I'd like to remind everyone that report sections are due tomorrow so that the sections can be put together and reviewed prior to submission.").
Submit complete and high-quality work	Quantify and communicate the problem if possible (e.g., "The written work submitted by team member X required revision so team member Y had to spend an hour editing it before putting the section into the report.").
Show up to meetings or show up late	Document the problem in an email (e.g., "Since you did not come to the meeting on Wednesday, …" or "I noticed that you are consistently late to the meetings. Would a different day or time work better for you?")
Come prepared to meetings/practice sessions	Clarify expectations about preparation in writing (e.g., "Make sure that your slides are complete before the presentation practice." "I noticed that not all of the slides were prepared before the last practice session and we took longer than expected. Everyone needs to finish their slides before the next practice.")
Respond to correspondence in a timely manner	Quantify and communicate the problem if possible (e.g., "I sent an email about this issue four days ago and have not heard a response. Our team rules state that a response should be sent within one business day.").
Participate in group discussions and decisions	Explicitly ask for input (e.g., at a meeting state: "Let's have everyone on the team provide input on this decision.")
Listen to other team members, controlling conversations and talking over others	Set aside time "open space" in meetings (at the end) where everyone on the team has the opportunity to voice issues or concerns (e.g. "Are there any other issues that we should discuss?"). It may be necessary to have a time limit (to avoid lengthy arguments and discussions). Team members should remember that not all issues need to be resolved in the meeting, but that an action plan for resolving the issue should be developed.
Participate in fair distribution of technical tasks and administrative tasks	Document the workload distribution. Identify task by type (e.g. writing tasks). Put the workload distribution in writing in the meeting agenda. The project manager can promote fairness (e.g., "In order to make sure that the technical and administrative work is divided equally…")