The Impact of Capstone Design Courses on New Engineering Graduates Preparation for Teamwork: A Mixed Methods Investigation

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Abstract: The present study is an investigation of the transition from Capstone design teams into teamwork settings in participants’ first job after graduation. Research participants were followed from graduation through the first three months on the job via a series of interviews and surveys. Results indicated that the majority (82%) of participants felt prepared for teamwork on their first job, but that there were incidents where graduates felt less prepared for the transition into work teams and these were explored in depth. The results of this analysis revealed a variety of mismatches between Capstone and workplace teams and leads to a call for deeper investigation of team cultures in both settings to better prepare new graduates.

Context

Capstone Design courses have become widespread in US engineering education settings and are spreading globally due to common accreditation practices and agreements for the transfer of licensure (ABET, 2019). Despite their prevalence, less is known about the impact of Capstone courses on the experiences of engineering graduates who enter the workplace. Previous work has identified a skills gap in new engineering graduates’ capacities and the demands of the workplace including deficits in project management and design (Dutson et al. 1997).

The present investigation delves into this transition out of Capstone via a longitudinal mixed-methods investigation of recent graduates from four Capstone programs at separate universities in the US. In this investigation, study participants are followed from graduation and into their first job via a series of surveys and qualitative interviews.

Data were collected across a broad range of skills, but the present study investigates the development of teamwork skills and the transfer of these skills into their first team experiences in the workplace. The investigation looks across the first three months of employment for the first cohort of study participants, and then delves more deeply into the experiences of those new graduates who were challenged by their first work team and felt less prepared by Capstone for their initial team experiences.

Research Question

The present study investigates the following research question: How do students’ experiences in Capstone Design Courses contribute to entry-level preparation for teamwork, and to what extent? This study is important for engineering education as Capstone Design courses are increasingly relied on to bridge this gap between university and work and they...
are often resource-intensive endeavours involving multiple internal and external stakeholders that increasingly stretch across both semesters of students’ senior year. With all of these resources committed, it is important to understand the impact of these courses on graduates’ transitions to the engineering workplace.

**Theoretical Context**

For this study, we use the Communities of Practice framework to understand how engineering organizations function, and to therefore understand what learning is necessary in order to participate in engineering organizations (Gilbuena et al. 2015). The framework describes three main features of any Community of Practice, which should also be present in most (if not all) of the engineering organizations that US engineering undergraduates enter after work. Those three features are related to the culture that is established within the community of practice: (1) “joint enterprise”, a recognition of the goals and purposes that the community must work together to accomplish; (2) “mutual engagement”, the back-and-forth creation of meaning by members of the community who work with or alongside each other; and (3) “shared repertoire”, an understanding of the patterns of activity and learning that allow for work to get done, which is firm but can be renegotiated.

On a surface level, Capstone is meant to prepare students for these Communities of Practice by creating contexts that resemble the contexts of work. In broad strokes, Capstone accomplishes student preparation for work because it puts students on teams that must negotiate decisions amongst themselves under constraints like budget and time (mutual engagement). It encourages them to use similar practices such as PowerPoint presentations, and software, such as SolidWorks, that they might use at work (shared repertoire). It invites them to shift their priorities from having high test scores and grades, to purposes like minimizing cost of a product, or performing rigorous and accurate tests of prototypes (joint enterprise).

Using this Communities of Practice framework, we can more deeply investigate the sociocultural learning needed to participate on teams at work. Gilbuena et al. (2015) describe multiple aspects of teamwork learning as being necessary for participation in the industry Community of Practice, such as:

- being aware of the strengths and skills of other team members
- distribution of labour, coordination of work with other team members
- conflict management

Importantly, within the Communities of Practice framework these aspects of learning are contextualized. Participants will not need to learn “conflict management” in general, but rather the specific styles, methods or strategies of conflict management that engineers engage in at work. Successful transfer of teamwork skills from Capstone will involve learning “how to do teamwork like an engineer” while still enrolled in the course. As such, this study investigates cultural differences between Capstone and work, in addition to instances where participants feel unprepared or ill-fitted for work because of the ways they learned to do teamwork.

**Methodology**

The data for this study comes from a larger study, the Capstone To Work project (Gewirtz et al. 2018). This project employed a sequential mixed-methods analysis, collecting data from engineering students starting before or during graduation and continuing over the course of the first three months of employment. The project also collected data past the first three months, into the first year of employment but this data is not used for this particular study.

Participants were recruited from 4 institutions from 3 different regions of the United States (Southwest, Southeast, and Northeast). Participants came from 3 mechanical engineering programs and one engineering science program. The programs ranged in size from 20-30
students per graduating class to larger programs with over 350 students per class. Each program included (but was not limited to) industry-sponsored projects, and had teams of generally 4 to 6 students. Study participants were 62 students who consented to the study and shared data in three forms: surveys, journals and interviews. Journals were not used for this study and so will not be discussed.

Surveys were sent to participants weekly for the first three months of work, totalling 12 surveys. Each survey asked participants about whether they had participated in various work activities that are also practiced in Capstone (e.g. engineering calculations, prototyping & testing, team meeting), and how prepared participants felt they were for those activities on a 7 point Likert-type scale with choices ranging from completely unprepared (1), to completely prepared (7), with the middle option (4) being “neither prepared nor unprepared.” For this study, participants’ answers to the “team meeting” activity on the survey were probed.

The semi-structured interview protocols probed participants’ experiences in their engineering environment (university or work), including their responsibilities, challenges and accomplishments, definitions of engineering, and perceptions of themselves as engineers. The initial interview used a common protocol for all participants. All subsequent interviews used a common base protocol, but then prompts tailored for each participant to follow up on previous data collection; for example, the three-month interviews explored experiences reported in the participant’s weekly surveys. This approach allowed us to maintain a general set of questions across participants for comparative analysis, while also exploring individual experiences in depth. It also allowed the interviewers to build a rapport with participants over time. All interviews were transcribed verbatim and identifying data was removed. Survey data were collected weekly for the first three months of employment, and then participants were interviewed again.

For quantitative data analysis in this study, survey data were averaged across the first twelve weeks of employment. Then, participants who scored a 5.0 and below (slightly prepared) on the seven-point scale were parsed and available interview data for these participants was explored to investigate challenges associated with transitioning from Capstone team experiences to team meetings at their first post-graduation job.

For qualitative data analysis in this study, narrative analysis techniques were used. This type of qualitative analysis is based on the premise that narratives are a natural way that people construct meaning. During semi-structured interviews, the interviewer and interviewee co-construct narratives together. Interviewees share experiences as part of an authentic connection with the interviewer, characterized by interviewer curiosity and interviewee reflection (Pawley, 2009). From the collected data from selected participants, the researchers reconstructed participant narratives with direct quotes from the interviews with participants. For each participant, two researchers read through all transcripts, and selected data to represent a condensed narrative from the participant’s own words (Kellam, Gerow, and Walther, 2015)

Findings

Teamwork (as defined by participating in team meetings) was the most frequent activity reported on the weekly surveys. 56 of 62 participants (or 93%) reported meeting with a team in their first 12 weeks of work. Of all surveyed activities, participants perceived themselves as most prepared to meet with their teams, with 46 participants (or 82% of participants reporting teamwork) reporting either moderate or complete preparation on average across the twelve weeks, scoring greater than 5 on the 7-point scale from the survey.

Of the 10 participants that reported a 5 (slightly prepared) or less regarding their team meetings preparedness, 6 participated in 3-month interviews. Of these 6, 4 narratives are constructed below from participants first two interviews across three months, indicating why they may have been unprepared for team work after Capstone. Table 1 shows the 12-week
average “Team Meetings” score for the 4 participants who felt unprepared when they transitioned to the workplace.

Table 1: Team Meetings Average Score for Participants who felt Unprepared for Teamwork

<table>
<thead>
<tr>
<th>Participant</th>
<th>‘Team Meetings’ Avg Score out of 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1105</td>
<td>5.0</td>
</tr>
<tr>
<td>3147</td>
<td>4.3</td>
</tr>
<tr>
<td>3148</td>
<td>4.5</td>
</tr>
<tr>
<td>4138</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Participant 1105

[Excerpts from the initial interview at graduation]

*We are a (Capstone) team of nine which is a pretty big team, and it’s kinda tough to manage because obviously all of us are peers, and then we meet with our TA once a week, but that doesn’t really give us a lot of structure.*

1105 felt his Capstone teammates were not motivated enough, and didn’t take responsibility for parts of the project.

*If there’s a problem, they let it sit until we have a meeting, and they’re like, "This is a problem." When they found it maybe the day after our last meeting*

Whenever [our TA] would tell us stuff to do, usually everyone was kinda good and they’d work hard to get it done, but if somebody else on the team was like, "Hey, we need to get this done" there wasn’t that same motivation.

The team waited on their TA for direction, but didn’t give the kind of feedback 1105 hoped for.

*Our TA didn’t play a big role in helping with any of our design stuff. He would occasionally have hints and suggestions, but for the most part we would meet with him once a week and he would say, "Okay. You guys either made good progress, or you guys need to pick it up a little bit."*

Work is a different scenario. 1105 works alongside his colleagues, but not with them. His boss depends on his work, and he relies on the fabrication department for his own work, but each engineer has their own projects. In his first three months, he asked colleagues a lot of questions, given their years of experience.

[Excerpts from the 3-month interview]

*I sent one drawing of my design through fabrication because I wanted to see if everything would fit. And my boss was like, “Oh, no, it’s gotta get done. Send it all through.” Then it didn’t end up fitting, so we wasted like two sheets of metal. The guys in fabrication were all huffy and puffy because we wasted two sheets of metal.*

Regarding his relationship with his boss, he often feels he is reining him in, “handling” him.

*His sense of reality on some stuff is a little skewed, how fast it’s done. A project will start, and it’ll have started a month ago. I traveled for four days out of one week and two days out of the other week and another two days this week. Then that month isn’t nearly as long as it seems when you’re out of the office half the time. That’s something he never really gets. He’s very good with customers and with the design work. He just takes a little handling.*
Part of 1105’s success at work involves negotiating work with his boss, a skill he didn’t develop with his TA in Capstone.

If he starts yelling about something, obviously I take it to heart, but I try not to take it personally because it’s just his reaction to things is usually big. I think I can learn to handle him a little better. He’s a very serious dude. But I think it’s getting better… I’m gaining an understanding of what needs to be done, so if he comes in, like before a trip, and asks if I’ve done xyz… I’m more like, “Oh, yeah, x and y are taken care of. Z is either under process or we couldn’t do it because of this.”

**Participant 3147**

[Excerpts from the initial interview at graduation]

I don’t like to consider myself a natural born leader, so it was putting myself out of that comfort zone and learning to step up for the (Capstone) team ‘cause none of my team members wanted to be the first (leader) either.

3147 was on a team of four women, and her program rotated leaders every few months during the project. She felt overall that her team worked very well together.

We’re kind of like on the same page of like how we all worked, and we’re very transparent with each other. So for example, if someone was overwhelmed with homework and was just like stressed out and like acting a certain way, we were all understanding that that was… like it wasn’t something personal or like something that we were in control of. But just being mindful of that person...

She did feel like she was too much of a pushover, reflecting on her experiences as project leader.

Whenever someone told me like “oh we should…” like I wasn’t strict on deadlines that we had to meet. So then a lot of our tasks or a lot of our deadlines kept being pushed back, and I wasn’t stern enough or… I didn’t hold my ground in terms of keeping those deadlines…

I would try to be a little bit more stern and assertive about certain deadlines that we had to meet or what I thought would have been best for the team in terms of the project and the timeline of the project.

At work, 3147 is in a different context as a liaison between multiple departments. She receives pressure from her executives, and needs to apply that pressure to teams of engineers or colleagues in other departments.

[Excerpts from the 3-month interview]

I was trying to help a different team ship out a product and because I had experience with the customer that we were dealing with, I knew there were certain access things that we had to include with the products that would keep the customer happy. So I intervened and I made sure that those coupons were included or at least built for them to ship out with the pack and I had a co-worker who was really reluctant in sending out those parts. I actually had executive people say, “No, you need to ship these out.” … making sure that whatever action that I take, even if it doesn’t necessarily make another person happy, that they still benefit the company and the customer as a whole.

She wasn’t sure that other departments knew what her department did, and they sometimes got dumped on with miscellaneous work.

I think they understand what I do as my position, but I don’t … think that they know what my group does.

She felt that her capstone experiences were a both a benefit and a detriment.

Coordinating how to do things and keeping that in mind definitely helped me hear, understand and try to negotiate time with the other departments that I have to work with,
because they're so swamped with other things and because we're not necessarily a priority. Trying to convince them and trying to make it a lot easier for them to take us in their responsibility is something that I guess I learned through the (Capstone) design clinic as well...I was very fortunate to have a (Capstone) group that was very considerate of each other and we never necessarily had any excuse or anything that hindered our relationship as a whole.

I wish that I ... Don't wish, but I think that other teams within my (Capstone) year probably have more experience and probably know how to handle (conflict) a lot more than I do.

In the end, she did feel that her non-assertive approach could be an asset.

My experience working with women engineers is very different compared to working with male engineers... I really think they're probably a lot more used to people being assertive and forcing things on them, and they appreciate the fact that there's someone who's willing to negotiate and actually understand what their other obligations are instead of being like, "No, you have to do this because I say so." Like understanding that they do have obligations, and being able to accommodate to their needs as well.

Participant 3148

Talking about her responsibility at the workplace, she underwent training with a software which wasn’t useful and had to learn the software on her own. She isn’t given enough responsibility in terms of client meetings and leadership. She specifically blames her department and co-workers and in one particular instant while describing her responsibilities she mentioned,

[Excerpts from the 3-month interview]

No, I feel like I shut up and am told what to do and I go home.

She further describes the reason why she doesn’t like the job.

The reason I started talking with this company in the first place is because I actually wanted to be on their energy team. I wanted to direct with energy and the need was in mechanical, so they hired me on the mechanical (team), which is funny because then I showed up and they have nothing for me. But anyways, the way the whole industry works is just so convoluted, and it feels backwards, and it seems problematic and there are too many egos. And I’m really finding that what I’m interested in is not this. Because I’m just like, there’s nothing interesting about my job to me.

She described the difference with work and Capstone team culture

I think one of the really big differences between work and Capstone is that, well two really big differences. The first is that with Capstone, my team members were all emotionally invested in the projects, like the senior project, so important. We're all working really hard, there's just a lot more behind the motivation and we were also working on it on weekends, late at night, all of the time.

Versus at work it's like, I'm working on three projects on different stages and we go home and it's over, we don't live with each other, we don't run into each other on the weekend. No one plans to work on anything over the weekend unless they really are in trouble and it's like, oh no, why did you come in on the weekend? So, I think the emotional investment and the co-worker boundaries are really different from Capstone.

I think everyone gets way too close (in Capstone). And I don't know if that's unique to that or not but yeah. That is nothing like the real workplace and so that detracts from the experience, but it was different in work- too professional.

Participant 4138

In Capstone, he had heavy teamwork-related responsibilities.
[Excerpts from the initial interview at graduation]

My role was communication director, so I learned a lot about when it's necessary to get a lot of people included in a conversation and what kind of different communication styles are appropriate for a conversation. When is it appropriate to set up a meeting as opposed to set up a phone call or just email someone or whatever? I was being sensitive to other people’s time, other people’s responsibilities, and choosing communication methods accordingly.

In the follow-up interview, the participant describes their more technical team role and responsibility in the workplace.

[Excerpts from the 3-month interview]

We were supposed to test a website we were developing. I was supposed to test the website. That was a little bit challenging because I was the only tester for it primarily. The one other tester was experienced, but he had other meetings he had to attend. So, I was designated to be the tester for that project, and there was a steep learning curve I had to go through, but fortunately some of my previous internships helped with that.

The participant went on to describe the difference between work and Capstone in terms of team meetings

Capstone didn't necessarily prepare you fully for having Skype calls every day, but it was the first kind of Skype meeting that you had. It was a gradual desensitization to Skype calls. (Capstone) was like a little peephole that I looked into in the world of Skype calls, and then once I got into work it was like this giant window of Skype calls. Yeah it was different.

Discussion and Conclusions

While quantitative results indicate that over 80% of engineering graduates are prepared for teamwork in their first post-graduation job, the qualitative results illustrate the plight of a few participants regarding what it means to be less prepared for teamwork once entering the engineering workplace. The experiences of each participant, and how their teams are structured in Capstone and the workplace, vary considerably. From the perspective of the Community of Practice framework, the teamwork culture that participants are challenged to integrate themselves into is not uniform and there were differences in the Capstone and work cultures in terms of how the joint enterprise, mutual engagement or shared repertoire were defined.

Each participant faced a different teamwork challenge that left them feeling unprepared, whether that challenge was conducting teamwork activities at a distance (4138), unfamiliar co-worker boundaries (3148), representing and pressuring departments (3147), or the need to rein your boss in (1105). There is no one teamwork challenge every participant had in common. However, there does seem to be something in common between each of these participant’s experiences, which can further explain their unpreparedness. Each participant demonstrates, through the narratives that unfold in the Capstone and then work context, a shift in the culture of teamwork. In general, each participant indicates that work culture is significantly unlike Capstone in some contexts, and that the culture of Capstone did not prepare them for work because of the difference. In general, participants were unprepared for teamwork because the teams functioned in an unfamiliar way, not because they lacked any universal teamwork skill.

To further examine the participants’ narratives through this lens, we can discuss the experiences of participant 3148 (in the interest of page length, we limit our in depth discussion to only one participant). A visual representation for participant 3148 was made to illustrate her transition from school to work, shown in Figure 1 below. During the Capstone design phase, she experienced interactions with her Capstone team members beyond work hours and outside of work places which resulted in closeness and strong interpersonal relations among the team members.
When she transitioned to the workplace, her interaction with the team members was professional and only during work hours. There was no interaction among the team members outside of the workplace or after hours. In addition, she needed to interact with her supervisor in the workplace individually, whereas during Capstone design, she only experienced group interactions with her Capstone design advisor. This indicates a shift in culture, in particular, to use the Communities of Practice framework, a shift in mutual engagement (Wenger, 1998). Engineers “do not cease to be [engineers] at five o’clock” (Wenger, 1998, p. 57). The way that employees engage with each other at work is different enough from the engineering teamwork she learned in school to make her feel unprepared, to make her question whether she belongs. In the end, she feels it would be preferable if there were no after-hours interactions in Capstone, as that would serve as better preparation for the world of work. The desired change is not necessarily part of the curriculum, or a missing skill at work, it is a change in the engineering culture she belonged to while in Capstone.

![Team Function- 3148](image)

Figure 1: Visual Representation of Team Functioning in Capstone Design and Workplace

These result affirm prior studies of engineering social climate and socialization. Engineering students develop an understanding of themselves in relation to their team (Tonso, 2006), which may not match what they experience at work. Newcomers are challenged to engage in teamwork activities at work (Yasar et al., 2007) that they may or may not have experienced in Capstone.

**Recommendations and Future Research**

Ultimately these findings have a few implications for Capstone education for engineering teamwork. The first implication would be that the Capstone programs investigated left the majority of participants feeling prepared for teamwork at their first job after graduation. This can be viewed as a type of endorsement for the benefits of Capstone education which often
contains much of the teamwork training in an engineering curriculum. However, there were mismatches between Capstone and workplace cultures that left participants feeling less prepared. Furthermore, participants felt unprepared in different ways. This also implies that there is not be a universal kind of engineering teamwork to prepare for, although that is uncertain given that this research is in a preliminary stage and analyses the experiences of a small group of people.

The findings suggest that future work should investigate the variability of teamwork culture both within Capstone and workplace contexts to better determine how students can be better prepared for their new Community of Practice and where training needs in Capstone should transition to socialization needs in the workplace Communities of Practice. Multiple contexts of engineering teamwork may exist in the workplace, and these may be the cause of unpreparedness for certain graduates rather than a lack of Capstone preparation. Finally, these results suggest that teaching students to recognize and contribute to multiple valid engineering teamwork cultures in Capstone may be the most appropriate approach for workplace preparation; more research would need to be done to be sure.

References


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