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New Engineers' First Three Months: A Study of the Transition from Capstone Design Courses to Workplaces

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Chris Gewirtz is PhD student in Engineering Education at Virginia Tech. His research interests revolve around how culture, history and identity influence assumptions made by engineers in their design practice, and how to change assumptions to form innovative and socially conscious engineers. He is particularly interested in humanitarian engineering design, where many traditional engineering assumptions fall apart.

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Marie C. Paretti is a Professor of Engineering Education at Virginia Tech, where she co-directs the Virginia Tech Engineering Communications Center (VTECC). Her research focuses on communication in engineering design, interdisciplinary communication and collaboration, design education, and gender in engineering. She was awarded a CAREER grant from the National Science Foundation to study expert teaching in capstone design courses, and is co-PI on numerous NSF grants exploring communication, design, and identity in engineering. Drawing on theories of situated learning and identity development, her work includes studies on the teaching and learning of communication, effective teaching practices in design education, the effects of differing design pedagogies on retention and motivation, the dynamics of cross-disciplinary collaboration in both academic and industry design environments, and gender and identity in engineering.

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Sidharth Arunkumar is pursuing his Masters in Mechanical Engineering at New Mexico Tech. His key area of interest is solid mechanics, and his research involves the study of conductive layers on wind turbine blades. He has worked on aircraft internal structures and Turbine casings for MNC clients as a Design Engineer, prior to his Masters at New Mexico Tech. He has also been involved as a research assistant, in the development of composite laminates for space applications. He is currently assisting research efforts to study students' transition from School to Work.

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Laura Rosenbauer is an engineering major and landscape studies minor at Smith College. She is a research assistant on the national and international capstone survey efforts and the development of CDHub 2.0. She is also assisting with a new research collaboration to study the transition from capstone design to work. She was a summer intern at the Urban Water Innovation Network, where she studied the thermodynamic and hydrologic properties of pavements. She is interested in a career in civil engineering.

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Jessica Deters is a PhD student at Virginia Tech in the Department of Engineering Education. She holds a B.S. in Applied Mathematics & Statistics and a minor in the McBride Honors Program in Public Affairs from the Colorado School of Mines. Jessica is engaging in projects that emphasize the sociotechnical nature of engineering with a focus on social justice and diversity. She aims to educate the next generation of engineers to understand and value the social, political, economic, environmental, and human implications of their designs.

Mr. Cristian Hernandez

New engineers' first three months: A study of the transition from capstone design courses to workplaces

Abstract

In preparing engineering students for the workplace, capstone classes provide unique opportunities for students to develop their professional identities and learn critical skills such as engineering design, teamwork, and self-directed learning (Lutz & Paretti). While existing research explores what and how students learn within these courses, we know much less about how capstone courses affect students' transitions into the workplace.

To address this gap, we are following 62 new graduates from four institutions during the participants' first 12 weeks of work. Participants were drawn from three mechanical engineering programs and one engineering science program. Women were intentionally oversampled in the study, with 29 participants (47%) identifying as female. Weekly surveys were used to collect quantitative data on what types of workplace activities participants engaged in (e.g., team meetings, project budgeting, CAD modeling, engineering calculations) and qualitative data on what challenges they experience in their early work experience.

In this paper, we present a descriptive analysis of the data to identify patterns across participants. Preliminary analysis of the quantitative data suggests that the most common activities for our participants were team meetings and project planning (mentioned by >70% of participants) compared to formal presentations and project budgeting (mentioned by <30% of participants). Preliminary analysis of the qualitative data suggests that participants' most challenging experiences clustered into two dominant groups: 1) self-directed learning, and 2) teamwork and communication.

The results are intended to inform both capstone faculty and industry to identify areas of strength and improvement. Our recommendations target current practices in capstone education including course design and structure as well as industry onboarding practices.

Introduction

Engineering education has seen numerous shifts over the past 30+ years designed to better prepare students for contemporary practice. These shifts include the development of capstone design courses in the late 1980s, the shift towards outcomes-based accreditation with the advent of EC 2000, the inclusion of cornerstone design in the first year, increased focus on learner-centered pedagogies, and continued attention to professional skills such as teamwork and communication. Yet, studies continue to point to significant gaps between school and work with respect to engineering practice[1-3]. These gaps are also highlighted in industry reports; for example, a survey by American Society of Mechanical Engineering (ASME) reported gaps in practical experience, systems perspectives, project management, problem solving, and design [4, 5].

Among the changes noted above, design courses, and particularly senior or capstone design, are typically seen as critical courses to bridge school and work. Capstone courses were initially developed to address industry complaints about gaps in new engineers' preparation and meet design requirements established by ABET in the 1990s [6]. Now ubiquitous, they share a number of common features across institutions and disciplines[7-9]. Most often they are structured as year-long team experiences that combine formal courses with extended projects, with an increasing emphasis on industry-sponsored projects [8]. Faculty goals for these courses center on helping students integrate their technical course work in ways that provide authentic, workplace-oriented design experiences [9-11].

Despite this emphasis on workplace preparation and multiple studies on the capstone course itself, few studies have examined students' transitions from capstone design to work to consider the effectiveness and appropriateness of the capstone experience. Moreover, the consistency of the gaps identified by industry and professional organizations points to the need for more work in this area, particularly around students' transitions between environments. Some key work is beginning to emerge that helps us better understand the relationships between school and work experiences. For example, Lauff et al. have identified significant differences in design practices between industry and capstone classrooms [12, 13]. Others have explored the experiences of new engineers more broadly, particularly through the Academic Pathways Study (APS) and subsequent Engineering Pathways Study (EPS). Work from these studies has included Korte's [14] exploration of the importance of peers and managers in new engineers' socialization processes as well as Brunhaver et al.'s [15] analysis of the supports and barriers in new engineers' experiences in the workplace. The latter study highlighted ways in which experiences such as employee education, help from managers and coworkers, and camaraderie served as both supports (when present) and barriers (when absent) to participants' transitions to the workplace. EPS researchers have also explored engineering career pathways [16, 17] and perceptions of key outcome measures [18].

To extend our knowledge of new engineers' experiences of the transition from school to work, we draw on data from a large multi-institution study to explore **1) what types of tasks and activities new engineers engage in during their first three months at work, and 2) what experiences they identify as most challenging in this transition**. Understanding what tasks newcomers participate in, and the challenges they face in those tasks, can help capstone coordinators and industry leaders alike in preparing new engineers for the workplace.

Methods

As noted in the previous section, data for this project is drawn from a larger multi-case study [19] across four institutions that uses a sequential explanatory mixed-method design [20], combining regular interviews with intensive survey data.

Research Sites

The research sites consist of three mechanical engineering (ME) programs, and one engineering science program. As one of the largest disciplines nationally and an archetypal design domain, ME offers a useful study focus. The sites range in size from a small program graduating 30-50 students annually to larger programs with over 350 graduates per year. All include at least a full-year of senior design; one has a four-semester design sequence that begins in students' junior year. All include industry-sponsored projects, with some having options that include faculty-sponsored projects, competition teams, and service projects. Finally, all use a course coordinator coupled with individual faculty and/or industry mentors for each team. Team sizes are generally 4-6 students. The sites are also geographically diverse (northeast, mid-Atlantic, mountain west, and southwest).

Sampling

Beginning in late spring 2017, we recruited participants from each of the four programs; recruitment included in-person or Skype visits to courses, followed by an email inviting participants to complete a screening survey. Our target was 20 participants for each of the larger programs and 10 participants from the smallest program; when more than 20 participants responded, the sample was stratified by gender (oversampling for women), race (oversampling for minorities), company size (seeking a balance), and employment sector (seeking a balance). We oversampled for both women and underrepresented minorities because prior research suggests that these groups may face unique challenges in entering both school and work communities of practice [21-27]. Oversampling these populations thus provides us with a more robust data set for examining their unique experiences. Company size and employment sector were included because these factors can potentially influence the ways in which newcomers experience onboarding.

At Site 1, we were able to use gender, race, company size, and employment sector as criteria: all women and underrepresented minorities who responded were included, and the remaining participants were selected to provide representation across company size and employment sector. At Sites 2-4, all participants who responded to the recruitment request were invited to participate in interviews. Table 1 summarizes the final participant profile across all four sites by selected demographic factors.

Table 1: Overview of Participant Demographics, Capstone Project Types, and Company Size

Demographic	**Number of Participants**					
Gender	*Female*	*Male*	*Other*			
	29	33	0			
Race	*White*	*Asian or Asian - American*	*Underrepresented Minority*	*Other*	*Unknown*	
	37	12	6	4	3	
Site	Site 1	Site 2	Site 3	Site 4		
	20	17	11	14		
Company Size	*Small*	*Medium*	*Large / Multinational*	*Unknown*	*Graduate School*	
	3	11	26	17	5	

This table includes all 62 individuals in Cohort 1 who participated in interviews at the conclusion of their capstone design course; it does not include 4 participants who served as the pilot study in which the instruments and data collection procedures were tested. Note that, as described under

“Response Rate and Participant Retention,” not all Cohort 1 participants who began the study have continued to participate, and those who have continued have participated at varying levels.

Data Collection

The full data set includes three forms of data collection for each participant:

- Background interview conducted at the end of the capstone course.
- Twice-weekly surveys during participant's first 12 weeks.
- Three follow-up interviews after approximately 3, 6, and 12 months of work.

In this paper, we focus on the weekly surveys: participants received two separate surveys each week: a short quantitative perceived preparedness survey sent each Tuesday via Qualtrics and a short qualitative reflection survey sent each Thursday via email. Participants received $6.25 for each completed survey, paid in 4-week increments (i.e. up to $50 for each 4-week set of surveys - up to $150 total).

The quantitative survey was informed by Experience Sampling Methodologies (ESM), in which the purpose of the instrument is to capture experiences as they happen in real time for participants [28-30]. The survey asked participants to identify activities in which they had participated within the past week. The list of possible activities was constructed based on common practices included in capstone design courses as workplace preparation (e.g. [7-9]) and refined by the research team to ensure coverage of a wide range of workplace activities. Figure 1 lists items included in the quantitative survey. For each item participants checked, the survey presented a follow up question about participants’ perceived preparation for that activity using a 7-point sliding scale with 7 being “Completely prepared” and 1 being “Completely unprepared.”

Please check all of the activities you’ve been involved with over the past week

- ❏ Team meetings within your unit or project team
- ❏ Project planning
- ❏ Writing reports
- ❏ Making formal presentations
- ❏ Performing engineering calculations
- ❏ Generating or refining design concepts
- ❏ Prototyping and testing designs
- ❏ Computer-aided modeling
- ❏ Meeting with clients
- ❏ Project budgeting (business financials)
- ❏ Other (please provide a short description)

Figure 1. Quantitative Survey Items

The qualitative survey contained a set of six reflective questions each week exploring participants’ most significant challenge and how their capstone experience did (or did not) prepare them for that challenge (Figure 2). The prompts were informed by Wallin [31] and Lutz et al. [32] on the use of reflection in capturing experiences of practice in engineering.

1. What was your biggest challenge this week?
2. What made it so challenging?
3. How did you approach this challenge?
4. To what extent did you feel prepared for this challenge based on your capstone design experience? Based on other experiences?
5. Is there anything you think your education might have done that would have better prepared you?
6. Are there any other workplace activities this week that you felt particularly well or poorly prepared for? If so, please explain.

Figure 2. Qualitative Survey Prompts: Reflective Questions

Response Rates and Participant Retention

Survey data collection began as soon as participants began work; since each participant began work at a different time, data collection has been staggered accordingly. As suggested above, participants did not have to complete every survey to remain in the study. Unless they explicitly indicated a desire to discontinue, they received both survey prompts each week for 12 weeks, and incentive payments were prorated according to the number of surveys completed. This approach allowed us to retain a high percentage of participants; of the 62 participants who began completing surveys, 59 completed at least one quantitative survey and 54 completed at least one qualitative response. All current participants have now completed their first 12 weeks of weeks of work. While this approach has allowed us to retain participants through the study, the cost is inconsistency across the survey data in that not every participant completed every survey. Table 2 summarizes the response patterns.

Table 2: Participant Response Rates

	Quantitative Surveys	Qualitative (Reflective) Surveys
Completed all 12	19	14
Completed 10-11	20	19
Completed 7-9	10	10
Ave. No. of Surveys Returned	9	9
Total. No. of Surveys Returned	540	484

We also note that response rates decrease slightly over time for both surveys, with more participants completing surveys during the first month than the third month, as shown in Table 3. Although not included in this analysis, we also note that at the time this paper was finalized, 3-month interviews have been conducted with 48 participants and 6-month interviews with 32 participants; follow-up interviews continue to be scheduled.

Table 3: Number of Participants by Month Completing at Least 1 Survey

	Quantitative Surveys	Qualitative (Reflective) Surveys
Month 1 (Weeks 1-4)	59	54
Month 2 (Weeks 5-8)	53	48
Month 3 (Weeks 9-12)	51	45

Quantitative Data Analysis

Elsewhere [33] we have reported on participants' perceived preparedness for the tasks covered by the short survey. For this paper, we present a broader descriptive account of what types of activities participants engaged in during their first, second, and third months at work. The intention of this analysis was to explore the research question, "**What types of tasks and activities new engineers engage in during their first three months at work?**" One limitation of this study with respect to this question is the inconsistency of the survey responses described above (i.e., not all participants completed the survey every week) and the relatively small sample size. Therefore, we have opted not to explore statistical analysis of activity patterns at this time. Future work will include grouping the survey responses into larger data sets and reporting on statistical differences between participants.

Qualitative Data Analysis

While the quantitative data helps describe the tasks in which participants engaged during their early employment, the qualitative data provides a deeper look into what aspects of work participants found most challenging. To analyze the responses to these surveys, we employed an *a priori* coding scheme based on work conducted by Lutz & Paretti identifying student-reported outcomes from capstone design courses. That work identified four categories of learning: engineering design, teamwork and communication, self-directed learning, and engineering identity. For this analysis, we employed their definitions, but also mapped the components of the quantitative survey to these categories to allow us to compare findings from the two types of surveys, as shown in Table 4. In addition, one new category emerged from the analysis, tentatively titled "Adulting," which refers to challenges participants experienced outside of the central work environment; this category included both non-work personal tasks (e.g. buying insurance) and work/life balance concerns.

Table 4: Emerging Themes from Qualitative Data Analysis

Code	**Definition [34]**	**Salient Quantitative Survey Items (*A Priori* Subcodes)**
Engineering Design	Both theoretical and practical knowledge resulting from engagement in a formal, systematic design process.	Engineering Calculations Generating/Refining Design Concepts CAD Modeling Project Budgeting Prototyping/Testing Designs
Teamwork & Communication	Interpersonal communicative skills learned through engaging in teamwork and managing the different kinds of relationships within senior design, both internal and external to the project team.	Client Meetings Team Meetings Formal Presentations Written Reports Project Planning
Self-Directed Learning	Autonomous learning skills and dispositions, including doing independent research, finding and vetting resources, and leveraging contacts with other professionals.	N/A
Engineering Identity	Coming to see themselves as engineers from an identity perspective, including feeling competent in one's skills and abilities as an engineer	N/A
"Adulting"	Challenges associated with being an independent adult including balancing personal and professional aspects of life as well as specific challenges associated with life outside of work.	N/A

Note that the quantitative survey items mentioned in the previous section fall entirely within the first two qualitative categories of Engineering Design and Teamwork & Communication: each of the quantitative survey items constituted a subcode within the relevant major code, and an "Other" subcode was added to each category to capture emergent experiences not covered by the existing subcodes. A number of new subcodes also emerged within each category; while a full discussion of each of these is beyond the scope of this paper, Appendix A provides a complete list of subcodes, with definitions and percent of respondents who indicated a challenge in that area at some point during their first three months.

Five members of the research team were trained on the codebook and deliberated about the meanings and applications of the codes until a consensus among all coders was reached. Following training, each researcher independently coded a subset of the data. The coded excerpts for each category were then reviewed by the research team, and definitions were refined and adjustments to the coding made in order to ensure that codes were applied with consistency and reliability.

Results

This section reports the results from both the quantitative and qualitative data analysis independently, with intersections and implications described in the Discussion section.

Quantitative Results

A total of 540surveys were completed by 59 participants over their first three months of work. The results provide a portrait of the types of activities our participants did (and did not) engage in across their first three months of work. The frequency of each work activity by month is shown in Figure 3, with the activities displayed from highest average frequency to lowest average frequency. Here, frequency is reported as percent of respondents, i.e. the percent of the respondents who submitted at least one survey for that month (of four possible) and who reported that activity at least once.

These results indicate that, by far, the most common activity new engineers engage in during their first three months are team meetings, with more than three-fourths of respondents consistently and increasingly identifying such meetings as part of their work. In addition, more than half of the respondents routinely engaged in project planning, engineering calculations, and generating/refining design concepts. Formal presentations, in contrast, were reported by fewer than a fourth of the participants. This is interesting in light of the qualitative analysis, where participants reported team meetings and formal presentations as challenges at similar rates. Notably, report writing and client meetings both saw gradual increases over the three months, with both rising to more than 50% of respondents' experiences by month three. This trend could be explained as new engineers becoming more fully integrated into project teams and having more work to report.

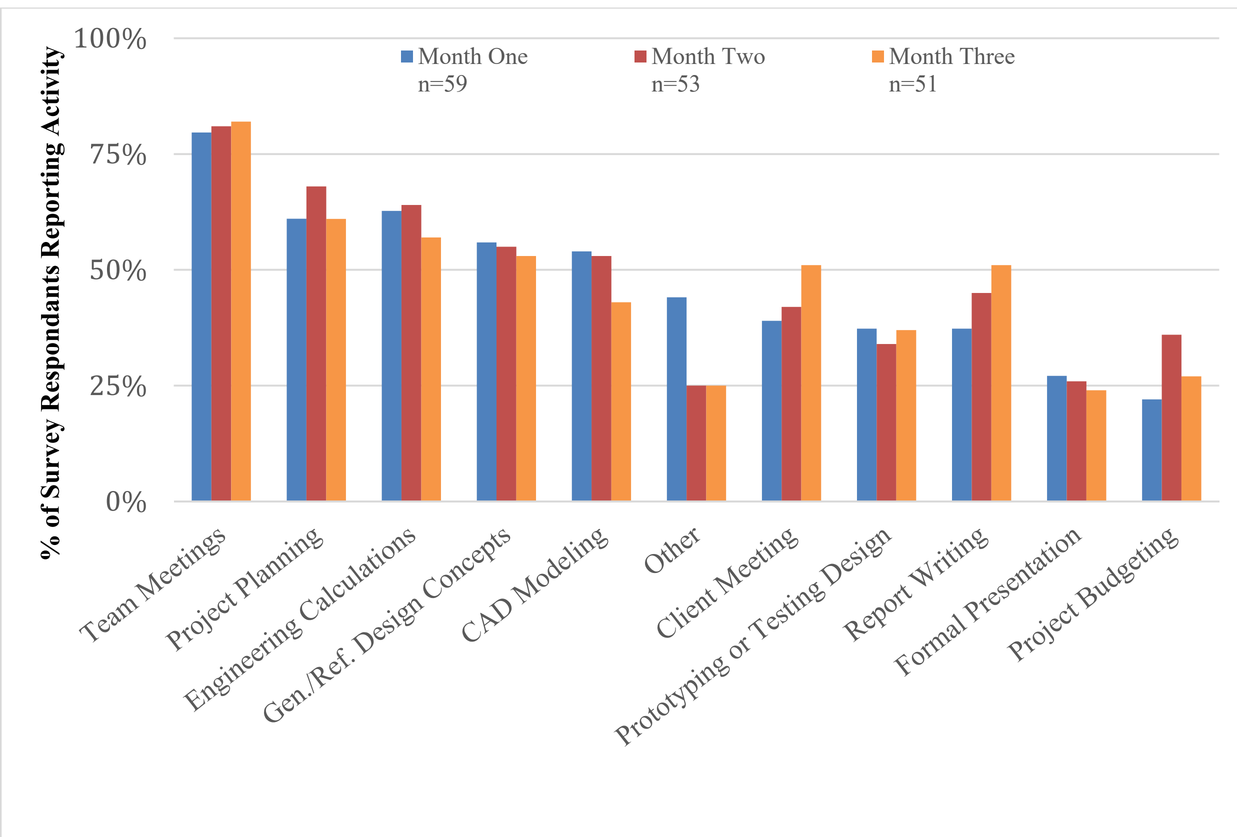

Figure 3: Frequency of Activities by Month for New Engineers

The one category that showed a marked decline, particularly between months 1 and 2, is “Other.” A word map of participant descriptions for this category, shown in Figure 4, highlights the prominence of training activities - events that are more likely in the first month. The word “week” was omitted from the word map.

Figure 4: Visualization of Participant Descriptions of “Other” Activities Completed during their First 12 Weeks of Work

Qualitative Results

While the analysis of participants’ quantitative survey responses provides an overview of what participants did during their first three months at work, their responses to the reflective survey illuminate the aspects of their job that participants found most challenging during those three months.

<u>General Patterns</u>

Several key patterns emerged across the qualitative responses. First, across the qualitative reflection, two categories seemed to dominate participants’ challenging experiences: (1) Teamwork and Communication and (2) Self-directed Learning. Table 5 summarizes the percent of participants reporting challenges in each of the major categories and each of the quantitative survey items.

Table 5: Coding Patterns

Code	Subcode	Percent of Participants (N=54)*
Engineering Design	Engineering Calculations	9%
	Generating/Refining Design Concepts	24%
	CAD Modeling	24%
	Project Budgeting	11%
	Prototyping/Testing Designs	13%
	Any Engineering Design Code	*83%*
Teamwork & Communication	Client Meetings	13%
	Team Meetings	20%
	Formal Presentations	22%
	Writing Reports	24%
	Project Planning	39%
	Any Teamwork & Communication Code	*93%*
Self-Directed Learning		92%
Identity Development		70%
Adulting		41%
Other		13%

*Percent of participants reporting at least one challenge associated with this area.

While most participants also reported challenges associated with engineering design, these challenges showed less consistency across the 12 weeks; that is, an engineering design issue might surface as the biggest challenge in one or two entries. In contrast, both Teamwork and Communication and Self-directed Learning emerged for most participants six or more times in 12 weeks. In Challenges related to self-directed learning in particular occurred regularly throughout most participants' responses, with almost half (24) describing challenges that included self-directed learning at least half of their responses and nearly two-thirds citing it at least four times across the 12 weeks.

Second, as suggested by the quantitative survey data, the nature of participants' challenges change over time, with challenges in four of the five categories decreasing over time. Challenges related to Teamwork and Communication, however, increased steadily as a percentage of the responses, as shown in Figure 5. This pattern parallels the increases in team meetings, report writing, and client meetings seen in the quantitative data. Figure 6 presents a more detailed account of the types of communication and teamwork challenges participants described. Here, participants increasingly reported challenges in client meetings, but also in interpersonal communication not only with coworkers but with supervisors, along with increasing challenges in project planning and logistics as they coordinated work among additional people. (Note that Appendix A provides definitions for each of the subcodes under Teamwork and Communication.)

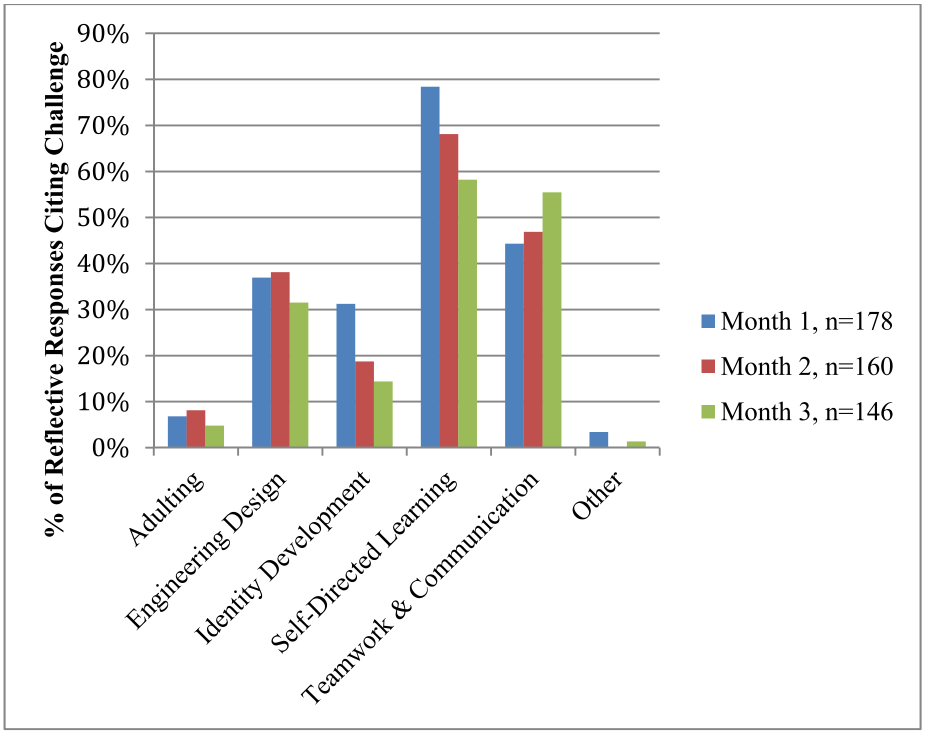

Figure 5: Change over Time in the Most Challenging Events Participants Report

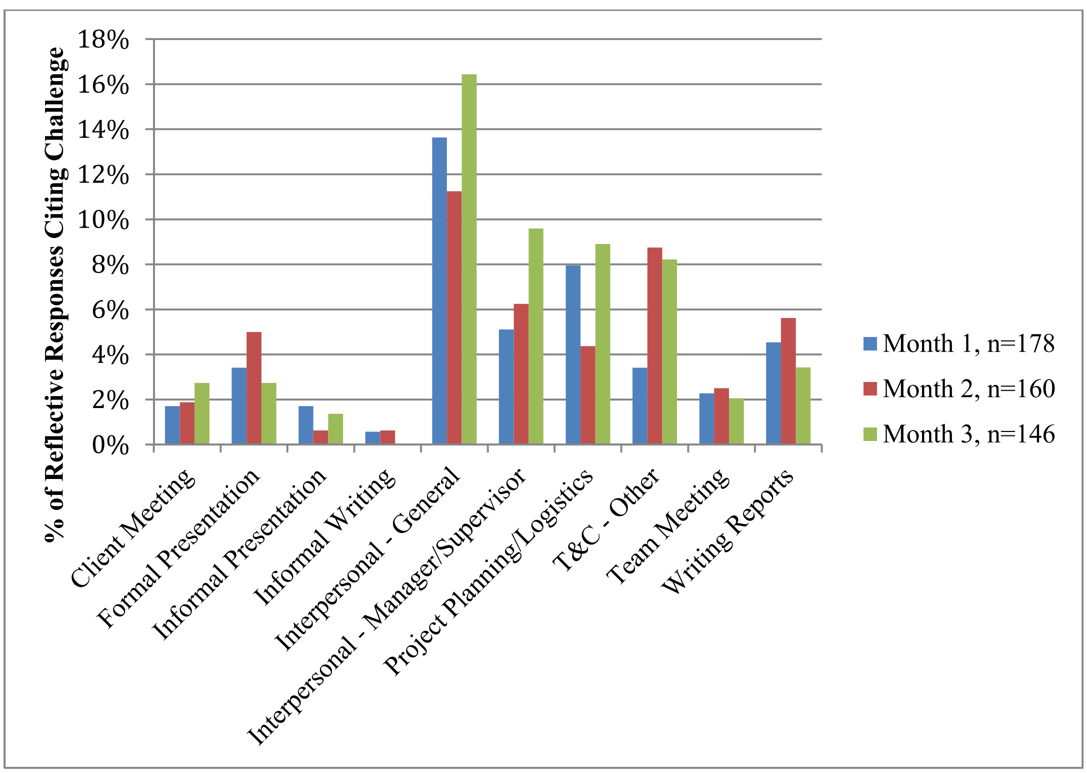

Figure 6: Change over Time in the Most Challenging Aspects of Teamwork and Communication Participants Report

Finally, we also noted that challenges were often interrelated. For example, a challenge related to understanding a particular technical concept associated with engineering design work might also involve a challenge associated with finding needed information - i.e. self-directed learning. Similarly, conflict with a colleague, categorized under the theme Teamwork and Communication, might be a conflict about getting needed information or identifying important work tasks, both linked to Self-directed Learning.

In the following subsections, we provide a more detailed look at two of the most prominent categories in participants' qualitative responses: Self-directed Learning and Teamwork and Communication. Quotations are identified by a numeric participant ID and the week (of 12) of the comment. Survey questions are included in italics where necessary to provide context.

<u>Self-Directed Learning</u>

As discussed above, Self-Directed Learning occurred multiple times for each participant across weeks. As noted above, none of the quantitative survey items are directly linked to this category, but initial analysis of the coded segments suggests three important themes: time management, learning new information, and identifying needed work.

With respect to time management, just over 50% of our participants talked about challenges associated with managing time across multiple projects, and half also described challenges associated with time pressure in meeting tight deadlines and high demands. These time management challenges are exemplified by the two quotes below.

> My biggest challenge this week has been my time management. My workload has been piling up over the past couple of weeks and trying to prioritize my tasks and deadlines has been difficult for me to get the hang of...What made it so challenging is that I think my failure to successfully organize and prioritize my tasks has resulted in extremely long work days. I have been averaging 10 hour days for the past 3 weeks. *- 1110M (Week 8)*

> *What was your biggest challenge this week?* Work management, after finishing multiple projects. *What made it so challenging?* After finishing two projects, I was left with little to do and I had to find projects to fill time. *How did you approach this challenge?* Looked into the upcoming projects and began work on them well ahead of when needed. *- 2160M (Week 9)*

With respect to learning new information, participants frequently described the challenge of encountering an unfamiliar task - new software, a new technical domain, a new process - and needing to understand it themselves with minimal direct guidance from their supervisors or colleagues. These participants, represented in the quotes below, talked about learning to ask necessary questions, discovering who to ask, searching the internet, and finding relevant documents and other resources at work to help them meet the challenge.

> *What was your biggest challenge this week?* My lack of knowledge on specific car subsystems for a project I was working on. *What made it so challenging?* It was very frustrating working with some very well-seasoned people in automotive when I didn't have the same experience as them. *How did you approach this challenge?* I asked

> questions on things that seemed appropriate but had to try to bridge the knowledge gap later on my own time..." - *1112F (Week 11)*

> Everyone I was working with on this project was traveling for other projects this week and I had gotten to the harder parts of the display design and did not have anyone to ask...I researched a lot of my problems on the internet and found out their solutions. - *1111M (Week 6)*

Finally, with respect to identifying needed work, more than 40% of our participants found significant down time, particularly in their first month at work, as they slowly learned what the company does, what work needed to be done, and how they could make themselves "useful" as they learned the ropes. The quote below demonstrates strategies for this learning.

> Now that I've been working at my company for a month I'm trying to find how I can establish myself beyond just being the new guy. How do I become an asset for this company and not just a recent grad trying to figure out how it all works...I'm trying to do better with investigating [these questions] for myself before asking my colleagues to save them time...I've also found that there are young employees who are working on things I'll soon have to do. So, I try and shadow them or jump in and see if I can help them to learn the skills before I need them and make my production more efficient. - *1108M (Week 4)*

Teamwork and Communication

While challenges associated with the quantitative survey items came up routinely in the qualitative data, by far the most common challenge in this category was linked to interpersonal communication with coworkers and supervisors. With supervisors, participants discussed challenges asking for vacation time, negotiating expectations of workload, or even writing emails to their supervisors with the proper etiquette. With co-workers, participants described other communication challenges, including arranging meetings at appropriate times, learning to openly ask questions to take advantage of their co-worker's experience, managing conflicts between ideas and approaches, and generally communicating across gaps of experience (and occasionally, age). The quote below describes a communication challenge that one participant faced in an attempt of "balancing wanting to work well with others and getting things done on time" that involved both her manager and a coworker.

> One manager still had to produce three documents and route them for approval which takes time -- maybe more than a day…. so I tried to delegate one item of documentation to his coworker. She said she would help out but in the end, the manager insisted that he do it….In hindsight I should have let his coworker complete the document and submit it for approval and have him go over it later. I did not do this because I did not want to step on anyone's toes but I realize there is a fine balance of wanting to work well with others and actually get things done on time. - *3146F (Week 2)*

Other less frequently mentioned aspects of Teamwork and Communication were project planning and team meetings, activities directly mirrored by the quantitative survey.

Discussion

The implications of the preliminary data from this study, especially regarding work activities and work challenges, have substantial bearing on how capstone courses and industry onboarding programs can help prepare students for the transition from school to work.

Work Activities

The activities participants reported during their first 12 weeks of work intersect to a high degree with the types of activities typically included in capstone courses, as well as with previous findings regarding engineering work. That is, more than three-fourths of our participants reported engaging in regular team meetings, and more than half reported activities around project planning and generating/refining design concepts. Report writing and client meetings, though less frequent in the early weeks, rose notably over the twelve weeks. Less frequent activities include both project budgeting and formal presentations.

These frequencies can help guide capstone faculty toward more informed decisions about how we prioritize skills development within these often heavily overloaded courses. For example, our results suggested that fewer than 25% of our participants engaged in formal presentations during their first three months, yet such presentations are common in capstone courses. These findings, particularly in conjunction with the types of teamwork and communication challenges participants report, indicate that students might be better served by focusing on informal small group presentations more typical of team meetings. This shift is corroborated by the measures of perceived preparedness by skill (reported in [33]).

In addition to offering insights that can inform capstone courses, our findings, and particularly the ways in which activity frequencies change month by month, yield insights into how newcomers become more integrated into their workplaces. Training activities (represented by "other") become less frequent, and report writing, client meetings and project budgeting become more frequent. These activities may be the tasks that newcomers take on as they earn the trust of their co-workers and supervisors, and seem to represent activities that have higher stakes and depend on less supervision. These patterns may reflect participants' increasing integration into workplace communities of practice.

Work Challenges

While the quantitative results highlight what activities participants engage in, the qualitative findings provide a deeper understanding of the specific types of challenges participants face. Though analysis of this data is preliminary, the emphasis on challenges associated with interpersonal interactions in both individual (e.g., peer and supervisor) and team settings further highlights the need for capstone courses to prepare students for this critical dimension of communication. Equally important, teamwork and communication challenges intersected with many of the other types of challenges participants described, reinforcing prior research highlighting the social nature of engineering work [1-3, 18, 35, 36] and, importantly, underscoring the ways in which the social is inextricably bound to the technical.

At the same time, many of our participants described multiple challenges associated with the broad domain of self-directed learning - an area that many capstone faculty themselves highlighting as they seek to encourage students to take ownership of their learning [10, 11]. Participants described challenges linked to learning new domains (software, technical concepts, equipment), managing their time among multiple projects, and learning how to make themselves useful in their early weeks at work. The prevalence of such challenges underscores the importance of self-direction within capstone courses, and suggests opportunities for more effectively supporting both capstone coordinators and project mentors in helping students learn these skills.

While these findings have multiple implications for capstone design education, one other point not addressed in the present analysis emerged routinely in participants' journal responses: the sense that while some of their challenges could be met through more effective capstone (or other) courses, they did not expect school to prepare them for every aspect of work. Some things, participants recognized, had to be learned on the job as they experienced their transition. Such comments bear further detailed analysis, but at a minimum they point to potential areas for employers to consider in both training and employee socialization. Though further analysis of the interview data (beyond the scope of this paper) is needed, our findings point to the need to ensure that new employees are effectively mentored as they learn the details of their job and the expectations and culture of the company.

Future Work

Overall, the results from this study have started to uncover how entry-level engineers *actually* spend their time and the activities they grapple with as they embark on their new careers. Emerging trends from the data indicate that some of these job responsibilities are specific to a company or industry and research participants did not expect these skills to be taught in a capstone design course. These industry specific tasks (e.g., travel rules, proprietary software, company specific budgeting software, etc.) are a place where companies can adjust their onboarding practices to assist with the transition of entry-level engineers. Future work will identify specific areas to help industry reflect upon their own procedures and increase the impact of junior engineers.

Additionally, future results can be used to refine capstone practices to better reflect work activities and challenges. For example, while the data from this study suggest that capstone courses should focus more intensely on informal teamwork and interpersonal communication, these areas are still broad aspects of engineering and encompass a wide range of an engineer's experiences of the workplace. As we look to interviews of newcomers and compare their workplace experiences to their capstone experiences, our research can be more specific about the nature of workplace communication and why it and other activities present challenges.

As noted above, the analysis presented here addresses only one piece of a larger longitudinal study. Future work will not only expand the analysis of the quantitative and qualitative survey responses, but also incorporate the 3, 6, and 12-month interviews to better understand how new engineers see the relationship between school - and specifically capstone design - and work. We expect this analysis to build on the findings here, but also to yield new themes that may not yet be adequately captured by our existing coding frame. Such analysis will also include explorations of how factors such as gender, race, and employment size and sector influence this transition.

In addition, the findings of this first cohort of participants will be used to refine the data collection instruments for a second round that will begin in the Spring of 2018. Our analysis of the Cohort 1 data has highlighted a number of potential changes to the quantitative survey (e.g. adding items such as “Training” and “Learning new processes, software, or equipment”) in particular to allow us to capture a more complex portrait of participants’ early work experiences.

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Appendix A: Full Code Book

Code	Subcode	Definition	% of Participants (N=54)
Adulting	Challenges associated with being an adult in the world rather than a student, being independent, including …		41%
	Non-work Personal Tasks	Balancing personal and professional aspects of life (e.g. having enough time for personal things, being tired at work because of personal activities)	15%
	Work/Life Balance	Anything associated with life outside work (buying a car, opening a bank account, relationships, family, etc.)	28%
Engineering Design	Challenges associated with engineering design and technical work, including …		83%
	Ambiguity/Uncertainty in Design	… uncertainty in the design process itself - e.g. not knowing which design decision to make or which approach to take	20%
	CAD Modeling	... modeling something using CAD or learning CAD software	24%
	Engineering Calculations	… performing engineering calculations	9%
	Engineering Design - Other	… any other aspect of technical engineering work	37%
	Equipment	… learning or working with new equipment	22%
	Generating/Refining Design Concepts	… creating or developing design concepts or plans	24%
	Problem/Requirement Definition	… defining the design problem itself, understanding requirements or specs	15%
	Project Budgeting	… developing or sticking to a project budget, cost estimating	11%
	Prototyping/Testing	… creating prototypes or testing designs	13%
	Software (non-CAD)	… using or learning software other than CAD	48%
	Engineering Design - Other	… any other aspect of engineering design or	

		technical work broadly	
Identity Development	Challenges associated with seeing oneself as an employee and/or an engineer, including …		70%
	Feeling competent	… feeling hesitant or uncertain about one's skills, abilities, and knowledge	41%
	Feeling part of the group	… feeling connected to or integrated with others at work; sense of belonging; fitting in	35%
	Identity - Other	… any other challenge associated with how the participant perceives themselves in the work environment	13%
	Learning role	… knowing what one's role is and/or how one fits into the team or company	35%
	Thinking like an engineer	… knowing how to make engineering decisions or justify ideas	7%
Self-Directed Learning	Challenges associated with managing and monitoring one's own time and activities, including …		93%
	Finding Resources	… knowing what resources are needed for a task and/or where to find them	33%
	Finding Work/Keeping busy	… finding things to do at work (e.g. during slow times or between projects)	43%
	Lack of knowledge	... not having the information, skills, background, etc. to take on a tasks; not knowing enough	70%
	SDL - Other	... not having the information, skills, background, etc. to take on a tasks; not knowing enough	54%
	Time Management	… balancing time among different work tasks	54%
	Time Pressure	… dealing with short/tight deadlines and/or a fast	52%

		pace at work	
	Work Ethic	… maintaining a commitment to work - e.g. long work days, staying engaged, doing routine or boring tasks	39%
Teamwork & Communication	Challenges associated with working in teams or communicating clearly, including		93%
	Client Meeting	… meeting with customers, clients, or other external stakeholders	13%
	Formal Presentation	… developing or giving a formal presentation	22%
	Informal Presentation	… developing or giving an informal presentation (e.g. to coworkers or supervisors)	11%
	Informal Writing	… writing something other than a formal report	4%
	Interpersonal - General	… communicating or interacting with others in the workplace (e.g. colleagues)	72%
	Interpersonal - Manager/Supervisor	… communicating or interacting with a manager, supervisor, or others higher up in the organization	41%
	Project Planning/Logistics	… organizing work among members of a team	39%
	T&C - Other	… any other aspect of communication and teamwork	33%
	Team Meeting	… conducting or participating in a meeting	20%
	Writing Reports	… … writing formal documents such as reports	24%
Other	Challenges not captures by other codes		13%