Engineering Graduates Perceived Preparedness for the First Three-Months of Work in Industry

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***Abstract*— This study explores recent engineering graduates' perceptions of preparedness during their first twelve weeks at work. Drawing on data from a multi-site, longitudinal, U.S.-based study, we analyze quantitative survey data collected weekly from two cohorts of participants during their first three months of work; an average of 83 participants provided survey responses each week, for a total of 998 responses and an average of 8.9 surveys per participant. Participants were asked to rate, on a scale of one to seven, how prepared they felt for given list of activities (e.g. CAD, technical calculations, report writing); the list of activities was derived from common activities in capstone design courses explicitly intended to mirror workplace tasks. The results indicate that participants generally felt well-prepared for their work in industry. In addition, perceived preparedness increases over the first three months of work as participants spend more time on the job. There are no significant differences in perceived preparedness by site, but women report significantly lower levels of preparedness ($p<0.05$) than men across all months. The findings suggest that in their transition to work, the participants in this study, while clearly recognizing their need to learn a great deal, also identified significant ways in which their education, and particularly their capstone design courses, prepared them for full-time engineering work. Set against persistent industry reports highlighting lack of preparedness among new graduates, the perceptions of the graduates themselves suggests that the definition of and expectations around preparedness may vary widely based on perspective and context, and more work is needed to understand what the term means to the various constituents involved.**

Keywords—capstone, transition to work, preparedness, competency gap, undergraduate engineering

I. Introduction and Literature Review

Engineering education is, in large part, focused on training engineers for the workplace. Several studies investigate what skills and competencies industry desires from graduates, as well as what competencies graduates commonly lack [1]–[3]. However, most of these studies focus on the perspective of industry professionals [4]–[6]. Moreover, studies in this realm that focus on new engineers tend to focus on barriers that graduates face when entering the workplace or what competencies students perceive as important to their work [7], [8]. At the same time, these studies typically focus on the gap between school and work – that is, to adopt a deficit model regarding the school to work transition. But, as recent research suggests, many new graduates do consider themselves prepared for work [9]. This perception raises important questions about what new graduates mean by preparedness, how they see themselves in the transition from student to professional engineer, and what aspects of engineering education prepared them for work.

These questions are particularly salient in light of the enduring critiques about the effectiveness of engineering education in preparing students for work – critiques that date back to the Mann report more than a hundred years ago and have resurfaced in government, academic, and industry reports regularly ever since [10]. Many scholars claim that a competency gap exists between the skills that engineers possess and the skills that they need in order to be successful in industry [1]–[3]. Research in this area often focuses on trying to identify the particular skills that are lacking in engineering graduates. For example, most studies claim that

teamwork and communication are among the most important skills but also among those most lacking in recent graduates [1], [2], [11], [12]. Other studies point to deficiencies in awareness of workplace expectations, practical preparation, leadership, technical communication, and management skills [1], [2].

While many studies suggest that engineering education is not effectively preparing students for the workplace, these studies largely focus on the perspective of industry. For example, Meier, Williams, and Humphreys (2000) explored the extent of the competency gap as perceived by business and industry leaders [4]. Similarly, Walther & Radcliffe (2007) cite several studies that base their claims of a competency gap on data collected from industry [3], [5], [6]. Even studies in this realm that focus on new engineers tend to focus on barriers that graduates face when entering the workplace or what competencies students perceive as important to and/or missing in their transition to work [7], [13].

As a result, whether from non-academic reports or academic research, whether examining the perspective of industry professionals or recent graduates, the tendency across all of these studies is to focus on the competency gap between school and work – that is, to adopt a deficit model when analyzing the school to work transition. In this study, in contrast, we frame our questions differently to understand the extent to which new engineers do perceive themselves as prepared for work, how their perceptions shift over their first three months of work, and whether those perceptions vary by gender. We focus on gender (self-identified by participants as part of a screen survey) because a number of prior studies have suggested gender differences in constructs such as competence beliefs and belonging, and the high number of women in this study allows us to compare the two populations statistically [15], [16]. Specifically, we investigate the following research questions:

RQ1: Are there differences in participants overall perceived preparedness across the first three months of work?

RQ2: Are there differences in men and women's perceived preparedness overall and by month during this period?

II. Methods

A recent multi-institutional, longitudinal, mixed-methods, U.S.-based study of new engineers' first year at work provides an ideal opportunity to investigate recent graduates' perceived preparedness. The broader study includes semi-structured interviews conducted just prior to graduation, quantitative and qualitative surveys during participants' first 12 weeks of work, and semi-structured interviews at 3, 6, and 12 months. The present paper analyzes the quantitative survey data from both cohorts of participants, building on previous analyses of the quantitative survey data from the first cohort of participants [9].

A. Site Descriptions

Participants were recruited from four universities (sites) across the U.S. Site one is a large land-grant university in the mid-Atlantic region. Site two is a small technical university in the West. Site three is a women's only liberal arts institution in the Northeast. Site four is a large state-university in the West. The sites were selected to represent a variety of engineering at different types of universities in different regions of the U.S. Students at sites one, two, and four were Mechanical Engineering graduates, and students from site three were Engineering Science graduates.

B. Data Collection and Participants

Two cohorts of students from four institutions across the United States were recruited. Cohort 1 graduated in 2017, and Cohort 2 graduated in 2018. The project initially recruited 140 graduating seniors (66 for Cohort 1 and 74 for Cohort 2).

An average of 83 participants (out of 140) provided survey responses each week across both cohorts, for a total of 998 responses and an average of 8.9 surveys per participant. Participants were asked to complete one survey per week for the first twelve weeks of work and were compensated for each completed survey. Participants were asked to rate, on a scale of one to seven (Table 1), how prepared they felt for each of 10 (Cohort 1) or 11 (Cohort 2) activities (Table 2); the list of activities was derived from common activities in capstone design courses explicitly intended to mirror workplace tasks. Participants were only asked to rate preparedness for the activities that they participated in during that week.

The survey items for either cohorts differed slightly: the surveys for Cohort 2 included training as an activity because the majority of the "other" category reported by Cohort 1 pertained to training, and training emerged as a theme in Cohort 1's qualitative surveys. In addition, an "overall" rating was added to the Cohort 2 surveys in order to gauge participants' overall perceived preparedness each week and account for work experiences beyond the activities list.

Importantly, to minimize attrition participants were sent surveys each week regardless of whether they responded the previous week (unless they explicitly withdrew from the study). While this approach created "holes' in the data since not every participant responded at every data collection point, it did allow us to maximize overall participant retention. Of the original 140 recruited, 120 responded to surveys at some point each week (and 71 remained in the study to provide 12-month interviews).

TABLE I. Weekly Survey Preparedness Scale

Rating	Description
1	Completely Unprepared
2	Moderately Unprepared
3	Slightly Unprepared
4	Neither Prepared nor Unprepared
5	Slightly Prepared
6	Moderately Prepared
7	Completely Prepared

TABLE II. WEEKLY SURVEY LIST OF ACTIVITIES

Cohort 1	**Cohort 2**
Team Meetings	Team Meetings
Project Planning	Project Planning
Report Writing	Writing Reports
Formal Presentation	Presentations
Engineering Calculations	Calculations
Refining Design Concepts	Design Concepts
Prototyping or Testing Design	Prototyping/Testing
CAD Modeling	CAD Modeling
Client Meeting	Client Meeting
Project Budgeting	Budgets
Other (please provide description)	**Training**
	Other (please provide description)
	Overall

C. *Data Analysis*

As mentioned above, not all participants completed a survey each week. To account for this missing data, only participants who completed at least one survey in each month (i.e., Weeks 1-4, Weeks 5-8, and Weeks 9-12) were included in the analysis, and responses were grouped and compared by month rather than week. Of the 62 participants in Cohort 1, 50 met this selection criteria, and of the 58 participants in Cohort 2, 42 met this selection criteria (total N=92). Of the 92 participants included in this analysis, 36 completed a survey for each of the 12 weeks.

In addition to missing weeks of data, participants only reported preparedness scores for the activities they participated in during any given week. To account for this missing data and to ensure consistency across cohorts (given the slight change in the weekly survey items – Table 2), each participant's reported activity preparedness scores for each week that they completed a survey were averaged together into a composite weekly preparedness score. Then, the weekly preparedness scores for Weeks 1-4 were averaged together to find the average Month 1 preparedness score. The same process was repeated for Weeks 5-8 (Month 2) and Weeks 9-12 (Month 3). These month-wise scores are used in the analysis.

D. *Combining Participants Across Site*

Differences in perceived preparedness between sites were examined in order to ensure that data from multiple sites could be combined into a single analysis. Across months, participants from different sites report comparable average levels of preparedness. Three one-way ANOVAs were conducted, revealing that site did not have a significant effect on average reported preparedness in any of the months. Importantly, given that three of the four sites included both men and women, while the fourth site had only women, the same test (one-way ANOVA) was used to compare perceived preparedness across the women at each site. There were no statistically significant differences across sites for female participants.

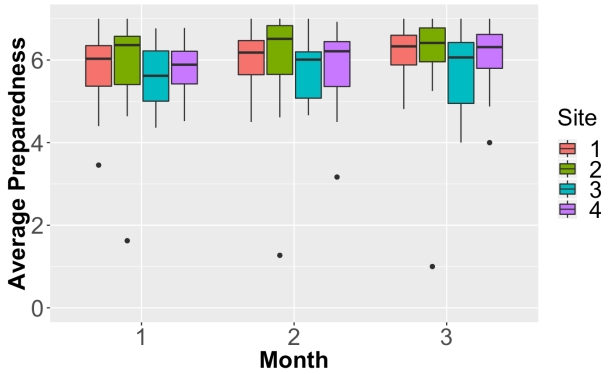

Fig. 1. Average overall reported preparedness by site

These results indicate that average reported levels of preparedness do not vary by site, and thus the data from each site can be combined into a larger analysis. This finding is consistent with the intentional similarities across capstone programs; that is, as noted elsewhere [14], all four sites focus on industry-oriented courses, creating a professional work atmosphere and intentionally preparing students for the norms and expectations of contemporary engineering workplaces. We note, however, that Fig. 1 highlights visible differences in the data that are not captured in the statistical tests. For example, sites two and three vary numerically and in practice, but these differences are balanced by sites one and four in the statistical analyses. Site three is a women's only liberal arts institution, while site two is a technical university. Perhaps most importantly, participants from sites one, two, and four graduated with a mechanical engineering degree while participants from site three graduated with an engineering science degree. The breadth of the degree and the diversity of career paths could account for the wider variation in perceived preparedness among site three participants, but a deeper exploration of the interview data is needed to better explore these possibilities.

III. RESULTS

Participants generally feel well-prepared for their work in industry, with participants reporting an average preparedness of 5.89 (i.e. just below "Moderately Prepared") across the first three months of work. Perceived preparedness increases over the first three months of work as participants spend more time on the job, rising from an average of 5.76 to 6.01. Women report significantly lower levels of preparedness ($p<0.05$) than men across all months. These results are discussed in more detail below by research question.

A. *RQ1: Differences Across First Three Months?*

As might be expected, average overall reported preparedness varied by month, increasing as participants spent more time on the job (Fig. 2). Friedman's test (the non-parametric equivalent of the repeated-measures ANOVA)

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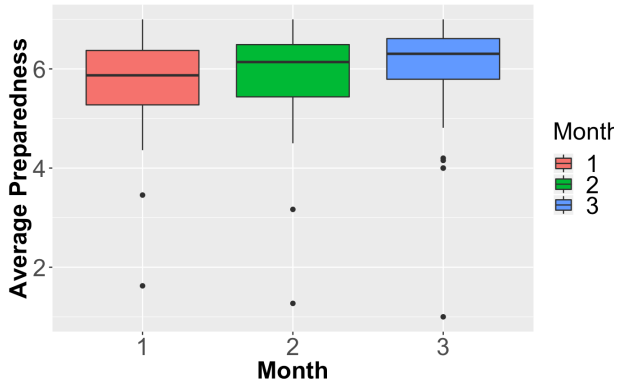

Fig. 2. Average overall reported preparedness by month

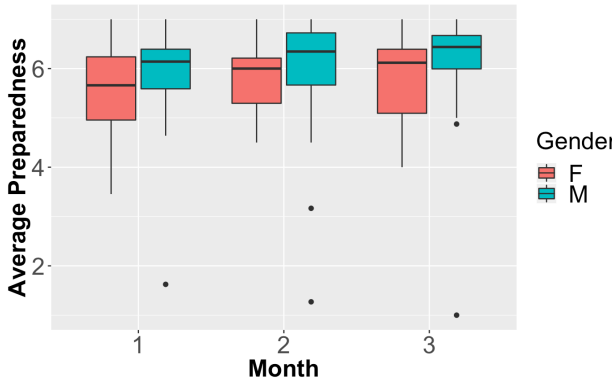

Fig. 3. Average overall reported preparedness by month and gender

resulted in a statistically significant difference between Month 1 (Mdn = 5.87) and Month 2 (Mdn = 6.13), p=0.023, as well as between Month 1 and Month 3 (Mdn=6.30), p=0.0003.

Overall, these results suggest that the longer participants spend in their engineering job, the more prepared they feel for the tasks they complete at work. Participants are acclimating to work and feeling more prepared over time. Given that in their pre-graduation interviews, participants' discussions of preparedness often centered on uncertainty about what their jobs would entail, this increase in perceived preparedness could be a function of participants learning their new workplace and expectations thus feeling more confident in their abilities.

B. RQ2: Differences by Gender?

By month, average overall reported preparedness varied by gender (Fig. 3), with men reporting consistently higher perceived preparedness – a difference that is statistically significant in Months 1, 2, and 3. Using the Wilcoxon Rank Sum Test (the non-parametric equivalent of the two-sample t-test) with the Bonferroni method to adjust for multiple comparisons, average reported preparedness in Month 1 differed significantly between men (Mdn = 6.12) and women (Mdn = 5.65), p=0.034. Average reported preparedness in Month 2 also differed significantly between men (Mdn = 6.34) and women (Mdn = 6.00), p=0.014, as well as in Month 3 (men (Mdn = 6.42) and women (Mdn = 6.11)), p=0.004.

Overall, these results suggest that as men and women spend more time on the job, men report feeling more prepared for their work than women – a finding consistent with previous research on gendered perceptions of competence [15]. Male participants start out reporting higher levels of perceived preparedness than female participants (i.e., the difference in Month 1 is significant), and over time, men still report significantly higher preparedness scores. This could indicate that men are acclimating more quickly than women to the workplace, that women face more challenges during their first three months of work than men [16], or, as in prior studies, that men are more likely to perceive that they "belong" in engineering [15]. These results also suggest that gender will be a relevant factor for future analyses of the qualitative data.

IV. Discussion

The results presented here indicate that for the participants in our study, self-reported preparedness falls within a narrow range (typically between 5 and 6.5) during their first three months at work; that is, most participants perceive themselves "moderately prepared" overall for engineering work. These results raise several questions that add to and push back against the competency gap narrative that has framed much of engineering education over the past 100 years. As noted earlier, both reports and research studies have pointed to a competency gap between the skills that engineers learn in school and the skills that they need to be successful in the workplace [1], [3], [17] – a gap that limits new engineers' ability to be productive members of their organizations. However, our results suggest that many new engineers do perceive themselves to be at least moderately prepared when they begin work, and their perceived preparedness increases as they spend more time on the job.

It is easy to dismiss these participants' perceptions by claiming that they are not in a position to judge their own preparedness or that they cannot evaluate their success at work. We note, however, that as we have reported elsewhere, responses to the qualitative surveys and interviews indicate that our participants are well aware of how much they have to learn on the job; self-directed learning, and particularly the need for new knowledge, was consistently one of the top challenges participants reported each week [18]. They were also keenly aware of the challenges they faced with respect to interpersonal communication and collaboration at work [14]. Across the qualitative data sources, they identify a range of ways in which they are learning on the job, coming up to speed and negotiating a complex range of new contexts and experiences. Moreover, the qualitative data also suggests that they are also continually getting informal feedback from supervisors and coworkers on their performance.

Such findings make it difficult to attribute participants' self-reported preparedness to overconfidence or treat it as evidence of the Dunning-Kruger effect [19]– that is, that they do not know enough to rate themselves accurately. These participants clearly know at least some of what they don't know. Instead, the findings suggest that these new engineers may have a different understanding of the concept of preparedness itself, and that they may be differently – perhaps

even better – attuned to the complex contextual shifts that happen as they move from residential universities – learning among groups of peers who are predominantly at their same age and experience levels while supported by faculty who focus on educating them – to workplaces where they are expected to be contributing members of multi-generational teams tasked with contributing to organizational profitability. While a deeper analysis of the qualitative data is needed to better understand what participants mean when they rate themselves as "moderately prepared," our initial explorations of their experiences of learning at work indicated that in part, they feel prepared to continue to learn, and to recognize what they need to learn [18].

V. Conclusion and Future Work

The findings from this study (and from the larger project from which our data are drawn) raise important questions about how we understand the relationship between engineering schools and engineering workplaces. First, the results invite us to question what we mean by preparedness, particularly in the context of the broad framework of higher education rather than narrowly focused vocational training. Who defines preparation and what do their definitions mean, or what should they mean? To what extent can we bridge the contextual differences between residential universities and contemporary workplaces. In other words, can school perfectly prepare engineers for work? Will there always be a gap between what students learn in school and what is expected of them at work? How can we better characterize the concept of preparedness to provide a more nuanced understanding of not only what it means to "be prepared" for engineering work, but of the ways in which undergraduate education can (or should) provide this preparation and the ways in which it cannot?

In light of these questions, our future work will further examine the data in this paper, examining potential variations in perceptions across variables such work activity (e.g. engineering calculations, prototyping, meetings), company size, and type of senior design project (industry-sponsored, faculty-sponsored, competition). In addition, a future mixed methods study will analyze the qualitative interview data to better understand how the participant in this project define preparedness and how they evaluated their own preparation in the context of their job responsibilities.

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