But Is It Really Design? Job Responsibilities of New Engineers

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Background

The relationship between university curricula and workplace practice is a persistent concern for engineering education scholars and practitioners. Design education has long served as one critical component of this relationship, with both cornerstone and capstone courses developed in part to help students gain practical experience in applying theoretical concepts to practical, industry-oriented problems. Capstone design courses in particular are often positioned as key steps in the transition from school to work, as Pembridge and Paretti's interviews with capstone faculty indicated [1]. Research on the school to work transitions suggests that these design experiences, as well as similar experiences across the curriculum, offer students a range of skills that serve them well in their professional careers, including life-long learning practices, deeper contextual understanding, practical skills in teamwork and communication, and more [2-6], and thus do help prepare students for engineering work.

Notably, however, while design has long been viewed as a central pillar of undergraduate coursework, scholars such as Russell and Vinsel [7-9] have long argued that in practice, few engineers engage in design as popularly conceptualized – that is, as novel product design. Far more often, they suggest, engineers work not as "innovators" but as "maintainers," those who focus on maintaining, and sometimes improving, existing products and processes. Work by scholars such as Trevelyan [10-12], Anderson et al [13], and others tends to substantiate that claim as these scholars document the complexity of engineering work in ways that include, but reach well beyond, innovative product development.

Yet while we have studies that, like Trevelyan's and Anderson et al.'s, capture the full range of tasks engineers do in their daily work, little research to date has explored the major job responsibilities for junior engineers during their first year. Without such knowledge, educators, including design educators, are at a disadvantage in effectively shaping curricula to support the school to work transition, and new graduates may not have an accurate, actionable understanding of engineering work. In this study, we seek to contribute to that conversation by exploring in more detail not the broader skills students need in the workplace [14] or the socio-technical complexity of engineering work [15], but the specific kinds of roles new graduates take on as they leave school and enter the engineering workforce. To that end, we ask the research question:

What are the major roles and responsibilities of new engineers in their first post-graduation position?

Literature Review: Research in Design and Design Education

We intentionally frame this paper with the provocative title question, "Is it really design?" The question reflects a much larger landscape of research on design and design education that has explored the nature of design thinking and practice across disciplines, as well as examined a range of pedagogical approaches to design education. Though a full review of these extensive bodies research is beyond the scope of this conference paper, a brief discussion of several relevant studies helps highlight the complexity of design, with definitions and practices varying both by domain and by individual perception. Within engineering education, landmark work by Dym et al. defines engineering design as "a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" [16]. Dym and colleagues go on to explore different dimensions of design thinking in terms of convergent and divergent dimensions, system-level analysis, decision-making, team dynamics, and modes of representation. Atman and colleagues, in their extensive work on design learning and practice, often drawn on key steps in the design process developed from a synthesis of engineering design textbooks that includes problem definition, information gathering, idea generation, modeling, feasibility analysis, evaluation, decision-making, and communication [17, 18]. This cycle, or variations on it, is often used in both cornerstone and capstone engineering classes, particularly in project-based courses focused on novel product design.

Looking more broadly across fields, Daly, Adams, and Bodnar, in their phenomenographic analysis of practitioners, identified six categories that capture participants' approaches to design, ranging from evidence-based decision-making to "freedom to create any of an endless number of possible outcomes that have never existing with more others and/or oneself within flexible and fluid boundaries" [19]. Their study drew participants from a wide range of fields that included not only different engineering disciplines, but also the sciences as well as instructional design, fashion, design, architecture, fine arts, and more. Their work draws on and contributes to the larger field of design studies that examines design not as an engineering-specific process but as a field-spanning way of thinking and engaging. They draw, for example, on earlier work by Goel and Pirolli in cognitive science that identified 12 key features that characterize the environments in which design happens, including size and complexity, interconnectivity of components, and feedback loops.

Interestingly, while Goeli and Pirolli, in their analysis, treated problem-solving a kind of design, work in the learning sciences by Jonassen instead positions design problems within the larger domain of problem-solving. Jonassen characterizes design as one kind of problem in a larger typology that also includes highly constrained situations such as logical or algorithmic problems as well as open-ended situations such as troubleshooting problems, diagnosis-solution problems, and dilemmas [20]. Jonassen's typology is particularly useful for examining the kinds of problems engineers confront in practice, and his work on "Engineers as Problem-Solvers" [21] is an important complement to work on engineers as designers (e.g., [22]). Design can be seen as one type of problem-solving, as Jonassen suggests, but equally, problem-solving can involve practices central to design thinking, as in Goeli and Pirolli's characterization.

As this necessarily brief discussion suggests, design, design processes, and design thinking are complex, sometimes contested concepts with a rich set of ongoing research questions. In asking the title question, then, our goal is less about trying to answer it in any definitive way either broadly or for the participants in our study. Instead, in examining the roles and responsibilities of new engineers, we ask the question as a way to invite educators to consider how our own framing of design as discussed and practiced in our courses connects to the work our students do once they graduate.

Methods

To answer our research question, we drew on data from a large multi-institution study of the school to work transition, the Capstone to Work, or C2W, project. Two cohorts of students from four universities were interviewed over the course of their first year of work. The full data set includes interviews at 3, 6, and 12 months of work. In this conference paper, we focus on a subset of the data: the 3-month interviews from one site. (For a full descriptions of the C2W methods, see Paretti et al. [23]).

Participants
The data set for this study includes 29 participants, all mechanical engineering graduates from a larger research-intensive state university; 19 identified as male and 10 identified as female (none identified as non-binary or other at the time of data collection). All participants graduated in the late 2010s. Participants were distributed across a range of sectors, as summarized in Table 1:

Table 1: Employment Sectors Represented

Sector	**# Participants**
Automotive Industry	11
Construction	3
Consulting – Not specified	2
Consumer Products	2
Defense	1
Electronics	1
Energy	1
Equipment Manufacturing	4
Manufacturing – Not specified	2
Software	2

Data Collection
Data was collected via semi-structured interviews, with the full interview protocol available in [23]. The protocol focused predominantly on new engineers' experiences of their transition from school to work, including what challenges they faced, what they considered major accomplishments, how prepared they were for their job, what aspects of their undergraduate experience enabled them to be prepared, and where they felt themselves unprepared. Pertinent to this analysis, the interviews began with a discussion of participants' current role in their jobs; we note, however, that because we had a team of interviewers (i.e., different participants were interviewed by different members of the research team) and job responsibilities were not a primary focus, the interviewers differed in the level of detail they elicited about participants' current work. All participants provided some indication of their current roles and responsibilities, but not all interviewers prompted for full details of the role. At the very briefest level, for example, the discussion of role may be as simple as "Yeah, it's not rocket science. It's HVAC." At the other end of the spectrum, some transcripts include one or more paragraphs, with prompting questions from the interviewer to clarify the work.

Data Analysis
Data analysis proceeded iteratively following Miles, Huberman, and Saldaña [24]. We began by using the general categories of engineering work provided by Trevelyan [25] to code the major tasks described by each participant, iteratively refining codes based on the data. In this analysis, we focused only on the ways participants described their primary roles and responsibilities rather than coding everything they did. For example, we did not code writing tasks unless the writing task was the participant's primary job; if they simply mentioned writing a report as a part of a larger role, it was not coded. In some cases, especially where the transcript was brief, we also returned to the original audio to identify the company the participant worked for, as that information could often clarify the work.

Once the major tasks for each participant had been identified, we then reviewed the excerpts as a whole to determine the primary role. Paretti completed the first pass, and then worked with the rest of the author team to negotiate all roles to consensus. The final roles, along with more detailed explanations and illustrative excerpts, are included in the results.

Results

The participants in our study held a wide range of primary roles, representing 13 different categories, as summarized in Table 2:

Table 2: Primary Roles of Participants after 3 Months of Work

Role	Definition	# of Participants
Process Engineer	Support, analyze, troubleshoot, and/or improve processes for manufacturing the company's products	6
Design Engineer	Support product design	6
Test Engineer	Develop, implement, and analyze empirical tests and/or simulations to support product design and improvement.	4
Manufacturing Engineer	Determine ways to manufacture the company's projects; design for manufacturing	3
Market Analyst	Analyze current market trends to identify new business opportunities	2
Construction Engineer	Provide equipment selection, drawings, diagrams, and equipment for building construction or remediation	2
Field Engineer	Provide on-site support for the product(s) produced by their company, including troubleshooting, repair, and service.	1
Plant Engineer	Oversee and improve the operation of an entire plant or facility; ensure operational compliance with relevant codes or standards.	1
Project Manager	Manage projects within the company	1
Quality Engineer	Analyze products and processes to ensure they meet quality standards	1
Site Engineer	Provide on-site support for building construction to ensure that third-party systems and equipment are received, installed, and functioning properly; troubleshoot problems and manage suppliers.	1
Software Engineer	Develop software	1

Process Engineers

Production engineering was one of the two most common roles held by participants (6 of 29); these new engineers were monitoring, troubleshooting, and improving production processes within their companies. These participants worked for a range of sectors (automotive, equipment manufacturing, consumer products), and their work focused on ensuring that production lines ran smoothly. For example, one participant describes her work as follows:

> So, what my project is we make a bunch of products to hit the demand for [company's product]. Well, we ... at the end of the run for the [product], there's always a bunch of

> leftover product because we schedule for over demand in case of various things that go bad along the process, which makes sense but we have an excess number of product and [Division] is like, "Oh, we're just covering ourselves to make sure that we don't run low and don't meet the customer's demand," but the problem is that then we're having outrageous amounts of scrap and so right now, that's basically my whole project. Just challenging everything from the number generation of how much product we're going to make for the [product] to the very end. So, I have to go through and basically break out every little element and every little calculation that we do, every little buffer that we add in. So, right now I'm setting up meetings with all the different teams that do the planning for the products and then marketing and things like that.

Another explained that at his manufacturing facility, "work is conducted based on what fires you're fighting that week. So what problems arise when ... the night shift on graveyard, and what problems arise over the weekend." Part of his work involved troubleshooting problems that arose, but he also focused on trying to improve the production process overall, as in the following example:

> I'll give you an example. One of our maintenance planners, how work was scheduled for them, they would have to go in on this website system data base and manually copy paste fields and there was a lot of opportunity for errors and mis-copied information in the wrong cells and then, also there were instances of losing data and it was just ... kind of a lot of sources for errors. It was a cumbersome task. What should have taken them seconds was having to take them five and 10 minutes because they had to wait on computer screens to load and the data base to sync and all that stuff. But, I [deal] with how does the data that they were pulling from is, how that's stored ... Can it easily be brought into Excel and be pulled in with query and can automatically be pulled in within seconds. Take a task that they have to complete say 50 times a day that was taking five to 10 minutes and reduce it down to five or 10 seconds. The work that they can then accomplish because they're not having to wait for the iteration time or implementation time is ... I mean, it's ... You go from hours and hours to minutes.

Design Engineers

Equally common, five of our participants had roles that were classified as design engineers, working to support the design or redesign of the company's products. However, two of those, working in the automotive industry, worked on what could be considered modular or configuration design; that is, the company manufactures custom utility trucks for clients, and the engineer's job was to identify the customer needs and then select the appropriate vehicle components to configure a vehicle to match those needs.

In the other four cases, participants were working in roles that are more commonly imagined as part of popular conceptions of product design; they were creating CAD drawings, creating prototypes, or analyzing designs for specific characteristics. One, a participant working in the electronics industry, describes her work as follows:

> So right now I actually am currently active on two projects, and both of them are mostly to do with developing a new product. And so a lot of what I'm doing now is I'm in the design phase, and so I get to do a lot of CAD work. I get to a print off a lot of prototypes and figure out whether this design fits best. I get to run it by the applications engineers and see what they think.

Another, focused on the analysis component of design in the defense industry, explains her most recent project:

> It was basically just research on certain welds, to see if it would fit a certain stress, and then writing a report on it. A calculation package, to send to the government to tell them whether this weld will be good and you can go ahead with it, or it's going to fail.

Test Engineers
All four test engineers in our study worked in the automotive industry. Their primary tasks included designing both simulations and empirical tests, analyzing data, and managing the testing schedule. For example, one participant explains,

> I'm considered a test engineer, and so basically I'm working in the dyno testing lab up here at [Company]. All of the development engines come through the lab that I work in […]. So once all the parts are designed and suppliers or whatnot are identified, then they will actually build a couple of engines and they come through and we basically run durability tests and such on them. […]My group is some of the smaller four cylinder turbo engines, and so we just finished testing our last engine of what we consider the output phase. Today they go through a couple of different design phases because obviously changes to the engine are needed once they figure that out through testing and whatnot. So we're about to enter the beta phase, and so we've got about 30 engines coming through our area that we'll be running tests on, so it's my job to make sure that those engines -- amongst my colleagues -- that those engines are getting the correct parts and that they're built on time and that they get set up to go into our actual dyno test cells. Then once they're in the cells we're responsible for checking up on the data and making sure that everything is kind of running smoothly, and basically overseeing the day to day operation of those engines when they're actually in the test cells.

Manufacturing Engineers
Three participants had roles classified as manufacturing engineers. Where production engineers focused specifically on making sure production lines ran as smoothly and efficiently as possible, the manufacturing engineers in our study focused on determining the most effective way to manufacture specific products and ensuring that designs produced by others were manufacturable. For example, one participant who began in production as preparation for her upcoming move into design engineering on her company's research and development team described a recent project as follows:

> A client came back from [before 2000] and said, "We want this same [product]." Well in [year] they were using a 2D CAD software. We had to make all these parts in 3D so we could then actually send them updated drawings and more realistic depictions of what they're actually going to be getting. Being able to go through their systems and find all these parts and know how everything is put together, how all the parts come together, how to build the bonds and all that, makes it a lot easier to transition into R&D. Because when you design a product you put together the way it's supposed to be for production

Another, working more on the design of a manufacturing facility, described his current project this way:

> Through the manufacturers, they have projects they wanna take, so they wanna start a new line, so they will hire us to procure the machinery, procure the conveyors and then program the conveyors and interlock the sensors. I'm on the control side of that, so I've been ... Most recently, we've been working for a [product] factory, putting in a new [product] line for them. What I've been doing is making a construction package for them.

Construction-related Roles

While production, design, and manufacturing engineering roles were most common, three participants had roles in the construction industry, two as construction engineers and one as a site engineer. One construction engineer, for example, worked for a consulting firm specializing in building acoustics, and his work focused on mitigating noise issues in new and existing buildings. As he explains, his job is to ask "Okay, what kind of noise is it? Let's get a recording. Where is it coming from? Try and identify where it's coming from and then try to identify a solution." In a similar vein, the other construction engineer has been "doing process and instrumentation diagrams" for a construction firm. In contrast, the site engineer was working at an active construction site testing and validating the functionality of the HVAC components and systems his company had selected and laid out. As he explains,

> Because I think we have about 320 pieces of equipment in the building, and they each have to go through their own checklist, functional performance tests, like another round of testing. Then the whole system has to be tested with the controls responses, how it works in terms of the building automation system. […] The work I'm doing, I wouldn't call it project budgeting, per se, but I deal with money every day. On site, we have to buy new materials, like something gets broken, I have to order a replacement. We just had to negotiate for a new indoor air conditioning unit for one of our electrical equipment rooms. Basically I was like looking at our budget and kind of seeing what we could afford. Basically negotiating back and forth with the vendor, and so on.

Other roles

The other participants in our study were distributed across a range of roles – one developing software, one working as a project manager, two analyzing current market trends to support product development at their organization, one plant engineer working on process safety and compliance at a nuclear facility, one acting as a field engineer to service and troubleshoot his company's project at customer or demo sites, and one working as a quality engineer, reviewing parts lists created by others to ensure that all relevant information is complete and correct.

Discussion and Conclusions

While capstone design courses, particularly in mechanical engineering and related disciplines, tend to focus on designing a product, only six of the 29 participants in this study were engaged in the kind of design work seen in capstone projects. Of those, four focused on what we might typically call novel design work, while two were configuring products using stock components to meet client needs. In our data set, work related to processes and manufacturing was more prominent, with six participants overseeing production processes, one helping to oversee an energy plant, and four focused on how products were being manufactured. Another four were test engineers, developing, overseeing, and analyzing product testing to ensure the functionality and performance of designs created by others.

In some cases, these roles match definitions of design as characterized by Dym et al. [16] Goel and Pirolli [26], Daly, et al. [19], and others. Most of the roles we identified, even when not classified as "design engineering," include at least some of the steps used to characterize the design process by Moore et al. [27] and used extensively by Atman and colleagues in studies of design education (e.g., [18, 28-30]: problem definition, information gathering, idea generation, modeling, feasibility analysis, evaluation, and decision-making are often present in the roles new engineers describe, though most of our participants were engaged in only some of these activities. The roles our participants described also potentially align with the broader outcome space of design approaches developed by Daly et al [19], including design as evidence-based decision-making, design as organized transition, and more.

Whether these participants would characterize their work as design, however, remains an open and under-explored question; many of our participants often used "problem-solving" or "troubleshooting" to explain their work, even when that work involved designing a solution to address the problem. As such, the kinds of problems and responsibilities these participants described appears more closely aligned to what Jonassen categorizes as Troubleshooting, Diagnosis-Solution, or Strategic Performance problems rather than Design problems [20]. These roles can involve or draw on design activities, processes, and ways of thinking, but may not be fully aligned, for example, with all 12 of the task characteristics identified by Goeli and Pirolli as central to design [26], even if they match Dym's 2005 definition of engineering design [16].

Importantly, as noted earlier, the kinds of design projects and practices included in capstone courses are intended to, and do, provide students with more than "design skills," however broadly or narrowly we define design ([1, 31]). In prior analyses of this data set, for example, we found that participants transferred a high number of skills, particularly related to teamwork, communication, and the ability to learn on the job, from their capstone courses specifically and their education more broadly [5, 6, 31].

The provocative question in this paper's title, then, may not be easily answered, and may depend heavily on whose definition(s) of design we draw on. Instead of answering the question, then, we suggest that the findings invite us, as design educators, to examine where we focus our energies and consider how engaging in novel product design supports the wide range of positions new graduates enter. We might ask, for example, whether novel product design is the optimum capstone experience given the wide array of post-graduation positions.

But even if this approach does offer the best, or at least an effective, capstone experience, understanding the kinds of roles new graduates take on can help us consider how we structure such design experiences. If our goal is to expose students to the full cycle of product development, particularly in the context of the transition from school to work, as suggested by Pembridge and Paretti's interviews with capstone educators across engineering fields ([1], then questions we might consider include

- Does novel product design as currently enacted provide sufficient exposure to manufacturing, testing, and production processes in ways that support graduates moving into that kind of work?
- Given the multi-faceted, iterative nature of design, are we exposing students to the right "mix" of design steps, in the right balance? Should we focus more heavily on problem

definition and information gathering to ensure that students are well prepared to understand the context in which they work? Or should we create projects and course sequences that allow more time for students to manufacture, test, troubleshoot, and iterate?

- How might we re-examine what and how we teach to ensure that students are exposed to the kinds of roles and practices expected of them in their new jobs?
- Beyond mechanical engineering, how confident are we that the capstone projects we are providing for students are reflective of and aligned with the kinds of post-graduation work they will encounter? What are the primary roles graduates of other fields take on?

A capstone course, even over two semesters, offers a very short project cycle for novice engineers; we argue that how to use that time effectively is a question that bears continuous reflection. As design educators broadly or capstone instructors more narrowly, we cannot possibly replicate all of the possible roles our students will go on to pursue, but the questions posed here bear regular re-examination as we continuously improve our courses and our curricula to support the next generation of engineers. Our findings, we hope, provide an important complement to studies on the skills needed in engineering work by providing a more concrete understanding of the roles those skills are directed toward. In doing so, they also provide design educators across the curriculum with insights that can help them better align curricula with post-graduation employment.

Limitations and Future Work

While the findings from this study raise productive questions about the relationships between students' undergraduate design experiences, particularly in capstone courses, and their future work as engineers, the data also has several important limitations.

First, as noted, while the interview protocol asked about job responsibilities and roles, the C2W project focused on students' experiences of the transition from school to work; as a result, not all interviewers probed detailed to build rich descriptions of participants' primary role. An interview protocol focused on job responsibilities in particular might yield more expansive or complex descriptions. We anticipate that the analysis of 6-month and 12-month interviews across all study sites will help deepen descriptions of these roles.

Second, this paper presents data from a single site after approximately three months of work, and thus may not fully capture the range of roles participants take on or the larger distribution of such roles across graduates. Preliminary analysis of that data suggests that the breadth of roles seen at this site are mirrored in the larger data set, though the balance may differ at a larger scale. Initial finding from the 3-month data across all four sites indicates that approximately a quarter of the participants functioned as design engineers in some capacity, with construction engineer and production engineer as the next most common roles. At the same time, more than a dozen other roles appeared, including roles not found at the site presented here, such as laboratory technician and risk analyst. As we finalize the full set of role definitions and coding data across the year, we look forward to sharing the findings with the design education community.

Third, as noted, the data were collected prior to the pandemic and, perhaps more importantly, prior to the current rapid expansion of uses of generative artificial intelligence. Yet we argue that the diversity of graduates' work experiences and the kinds of work they do are likely to remain similar for some time. GAI is already a critical tool in this work, but the kinds of troubleshooting and problem-solving our participants engaged in may well continue to need human as well as artificial intelligence to solve. If anything, the integration of GAI into engineering demands even more updating of our courses to ensure that students are fully prepared to leverage these industry-critical tools across a wide range of existing and emerging roles. Moreover, even post-pandemic data might not yet capture the changes being introduced by GAI; a new set of interviews collected over the next few years would be particularly helpful in understanding how the "AI revolution" may be impacting the roles available to new engineers.

Acknowledgements

This material is based on work supported by the National Science Foundation under Grant Nos. 1607811 and 2528603. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We also want to thank Dr. Margaret Webb for her role in early reviews of the data to help conceptualize engineering roles.

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