Informal Mentorship of New Engineers in the Workplace

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Introduction

Despite the long history of research on engineering education, little is understood about the transition from school to work in the modern engineering workforce. Historically, one model of this transition was formal apprenticeship (Wilson, 1965). However, this model of on-the-job training is all but dead in modern engineering. That said some form of apprenticeship or mentorship must survive today, as new engineers must learn from more senior engineers on the job. This may take the form of direct one-on-one teaching, passive supervision, occasional but regular feedback and correction, or any number of mentorship-like behaviors. Unfortunately, while we may guess at the types of mentorship that happens in the workplace, the research literature contains little to no direct observation and analysis of characteristics and structure of modern informal mentorship. Therefore we ask: How do new engineers gain experience and knowledge in the workforce?

In order to address this question we propose to expand a particular model (Stevens, et al., 2008) of how undergraduate engineer students succeed or fail to find success in engineering school, to explain how engineering students gradually become engineers. In this model "becoming an engineer" is the result of the interaction of three processes of learning (Stevens, et al. 2008). The first is the development of *accountable disciplinary knowledge.* This notion is based on a discipline- and context-specific view of knowledge, which argues that different kinds of knowledge *counts* as disciplinary knowledge in different environments, times, and with different people (Hall and Stevens, 1995). Therefore, knowledge that counts in engineering classrooms may look wildly different than knowledge needed in messy, real world workplace situations. Mentors may play an important role in this process by both providing, correcting, or modeling "correct" disciplinary knowledge as needed to hold the new engineer accountable, which in turn may help new engineers develop their skills and understanding.

The second process of becoming an engineer is the formation of an identity as an engineer. This builds on previous work about how learners develop identities (i.e. notions of self) over time in relation to their experiences within or against disciplines to determine the types of people they become (Becker and Carper, 1956; Holland, et al., 1988). In other words, how new engineers see themselves as fitting into a vision of what it means to be an engineer over time and in a particular context. Importantly, this process is not entirely learner directed, but instead is shaped by how learners are positioned and viewed by other people and institutional practices. This is important for our work in understanding how mentorship relations between new and more senior engineers—as well as larger workplace culture—molds engineers' identities throughout their early careers.

The final process involved in the becoming an engineer model is navigating through engineering education. This is defined most simply as how students traverse the various pathways and roadblocks that make up a particular learning environment, in order to become recognized as an engineer. Of course, we adapt this notion to argue that new engineers are presented with professional environments—that can still be thought of as places of learning—in which they must develop not only skills and knowledge about their discipline, but also about the distinct culture of their workplace. More senior engineers are part of this culture and may act as helpful mentors, hostile adversaries, or anything in between. Furthermore, navigating new workplaces involves the levels of responsibility and new positions within a hierarchy. For example, engineering interns differ in responsibility from new full-time engineers, and in some cases individuals navigate from the former to the latter as part of their career path.

In this work, we extend this idea of becoming an engineer to explore how new engineers interact with more senior engineers in the workplace. To borrow the language of Lave and Wenger (1991), we are interested in how newcomers learn from and eventually become old timers in engineering. We assume these interactions happen in many ways, including person-to-person and at larger sociocultural levels. Here we attempt to describe the diffuse ways these interactions happen. This raises a problem with language as no one word can fully capture the phenomenon. Therefore, when describing the interactions between newcomers and old timers, we have chosen to use the word *mentorship.* We do so, with some caveats. We recognize a single word does not capture the diffusion of interaction, and that phrases like "newcomers' interactions with old timers" are cumbersome. For the sake of concision we selected "mentorship," as it seems to be the most common phrase in the literature. A search on article in the Journal of Engineering Education reveals 223 uses of "mentor" and only 37 of "apprentice." Furthermore, we feel the word "teacher" even less appropriate for this context. Throughout the remainder of this article the reader should assume that the word mentorship does not automatically refer to one-on-one situations and rather to both those and larger social interactions.

We draw on a large ethnographic study of new engineers in their first year on the job to characterize the role and nature of mentorship-like training in the modern engineering workforce. In the following, we first provide a background in ethnographic research and argue for its utility in understanding questions of real world engineering practices. Next, we provide an overview of our data collection and analysis. After this, we offer preliminary findings, first by giving a short summary of the initial characteristics of observed mentorship practices. We will then illustrate these general findings by laying out four vignettes of interactions between three new engineers and three senior engineers in the same workplace in order to provide details that deepen and enrich our understanding of mentorship in the modern engineering workplace. We use these findings to suggest ways that engineering schools and companies can help support and enrich the learning of new engineers in the workforce.

Methods and Data Collection

In attempting to understand learning in the workplace, the likely most familiar methods to engineering education are interviews and surveys that directly question a number of engineers about their experiences. One example of research in this vein is the *Engineering Pathways Study* (see Brunhaver, et al. 2017). These methods can certainly describe ways in which people learn from others, however, we argue they are not fully adequate. Interviews and surveys present retrospective descriptions of experiences. That is, the participant is being asked to *recall* events. This can give you some detail about *who* they learn from and perhaps descriptions of very salient events from the learner's point of view, but it is difficult to describe the *how* of learning from these methods. To gather a full picture of learning and mentorship in the workplace requires real time, direct observation. That is not to say that interviews and surveys are not useful—we employ them ourselves—but that they are limited in scope. Direct observation allows for the description of phenomena that may never be uncovered by other means. For example, our research finds that learner/mentor interactions are often brief and sporadic. This makes them less likely to be recalled by the learner in an interview, and yet we can see their direct influence over the new engineer's behavior. For our ends, to understand the full spectrum of both the types of mentorship encountered by new engineers, the when and why they occur, and the impact they have on an individual's development as an engineer, we must follow new engineers on the job and collect the richest and deepest data possible. The specific approach we have taken has been called *person-centered ethnography* (Hollan and Wellenkamp, 1993; LeVine, 1982, Stevens, O'Connor, & Garrison, 2005). This term highlights both our interest in how people become engineers and that context shapes this becoming.

Data from this work come from a large ethnographic study of the school-to-work transition of early career engineers. In total we observed and interviewed 20 new engineers (15 were both observed and interviewed and 5 were interviewed only) within their first two years in the workforce (including both undergraduate co-ops/interns and newly graduated engineers) from 10 engineering companies as they worked over several months. Data sources included:

- Direct observations in the workplace, supported by written field notes taken while observing activities.
- Informal interviews conducted in the course of our observations (both retrospective and spontaneous).
- Video-recordings and audio-recordings of engineering work activities (roughly 100 hours).
- Collection of materials and artifacts that are produced by participants (and freely shared) during their work, including photocopies of paper documents; copies of electronic documents, such as pdfs, emails, and text messages created in the course of observed activities; and photographs of temporary surfaces like whiteboards where participants have written while working.

In addition to these 20 focal new engineer participants, we also collected similar data from 21 non-focal participants who were more senior engineers at the various field sites as they interacted with the focal participants.

The primary analytic approach for this sort of ethnographic research is *constant comparative analysis* (Strauss & Corbin, 1998). In simple terms, this process involves iterative cycles of analysis, which identify objects (in the most broad sense) of interest that, in turn, refine later data collection. So, our analysis involves concurrent engagement in data collection and data analysis, leading to a preliminary "grounded theory" (Glaser & Strauss, 1967). In conducting our analysis, we use the standard three-level coding procedures for constant comparative analysis: 1) *open coding* involving the initial segmentation of data into preliminary categories; 2) *axial coding* organizing preliminary categories into broader themes; and 3) *selective coding*, which refines categories and themes into an overarching theory. Additionally, we adopted the further methodological approach of *interaction analysis* (Jordan and Henderson 1995). Interaction analysis uses video as a primary data source and involves repeated viewing in order to provide an in-depth analysis of the interactions that shape thought and behavior through talk, nonverbal cues, and artifacts. Therefore, the open coding level of analysis involved creating content logs—rough descriptions of the action with annotations of particularly compelling sections—of video. These logs contained empirical descriptions of action as well as initial conjectures to explain how new engineers interacted with their new workplace setting. Through this process we progressively narrowed our analytical foci into several themes of interest. The following descriptions are the preliminary findings revolving one such theme—mentorship.

Data Analysis

In general, our analysis finds that while mentorship on the job is quite common—there is some form of interaction in every field site that we could categorize as mentorship-like—individual engineer's stories are quite diverse with regard to mentorship interactions. These on the job interactions appear to be mostly *ad hoc* and fleeting with rare instances of direct intentional instruction (as opposed to in-the-moment correction or feedback). Furthermore, learning arrangements between new and more senior engineers are constrained by several factors, including the rigidity of organizational hierarchy, the thoroughness of division of labor, and the senior engineer's willingness to actively mentor. For example, we see how new engineers attempt to gain knowledge and experiences from more senior engineers, but are sometimes rebuked due to corporate structure and hierarchy. Yet, at the same time, we see examples of new engineers successfully finding senior co-workers who recognize the importance of training them to navigate these restrictive structures and hierarchies for the benefit of not only the new engineer, but also the senior engineer and the company itself. We find a variety of learning arrangements, including isolated new engineers struggling to find a place in their new work, while also learning new skills, and fully collaborative work between new and senior engineers.

In the following section, we will provide four vignettes that illustrate real world examples of mentorship. We will describe the context for each instance of mentorship, as well has how it relates to the three dimensions of becoming an engineer. These vignettes are meant to provide a snapshot of the current state of mentorship for new engineers in the modern workforce. As such, they were chosen because they clearly and richly express qualities of interaction seen in the larger data corpus. Furthermore, these vignettes provide a balance between the depth and breadth of our portrayal. By narrowing our scope to describe a few individual instances of mentorship in a single field site, we obviously miss whole relationships between any pair of new and more senior engineer over longer periods of time and over multiple sites. Likewise, these vignettes might not generalize past a case study of how a single work culture shapes mentorship. However, the single field site allows us to more clearly compare different interactions within a single larger context. Also, by providing examples of multiple relationships with one new engineer and one senior engineer we hope to overcome some of the lack of depth that a full case study could provide.

Vignette 1

As mentioned above, mentorship in modern engineering workplaces is often *ad hoc* and fleeting. The following vignette is an example of a typical type of interaction that is not planned and emerges momentarily to address a specific purpose before passing quickly. This vignette also shows how these types of interactions seem occasioned by the fact that new engineers frequently work in isolation and more senior engineers only sometimes check in on the progress of their work or in order to correct them.

This case involves a chemical engineer, Curtis, who works in the position of developmental engineer for Large Southern Steel Mill. The title of "developmental engineer" was part of a program initiated by the company to bring in and train new engineering talent, in order to inculcate them into the ways of the company (thus not requiring the "re-training" that hiring more senior engineers would require) and to lessen effects of losing the knowledge of older engineers when they retire. Part of the developmental training involves rotating the engineers to different parts of the mill every few months in order to expose them to the mill's full functioning. After spending three months working and learning about a chemical treatment section of the mill (which he enjoyed), Curtis was moved into a position in the melt shop (the part of the plant responsible for processing scrap metal and casting semi-finished steel slabs, which is the first part of stainless steel production). Here Curtis found himself to be at square one, with very few responsibilities and little guidance.

During an early field visit to Large Southern Steel Mill, Curtis was sitting quietly at his desk in front of his computer. On this particular day, Curtis had just been given an assignment to make a form to use when measuring the dimensions of steel slabs in the cooling yard. As he was designing the form in Excel, Will, a senior chemical engineer who was ostensibly Curtis's supervisor, glanced over and the following exchange occurred:

Turn	Time	Speaker	Quote or [*action*]
1	[00:04:09]	Curtis Researcher	[*Both giggle quietly at a humorous remark made by someone in the next cubicle*]
2	[00:04:10]	Will	[*Turning to the researcher from his desk to Curtis's left*] What's up?
3		Researcher	Nothing. Watching him. [*Nodding towards Curtis*]
4	[00:04:13]	Will	Oh okay. [*Looks at Curtis's computer*] Ohh, Curtis, you're doing the form?
5	[00:04:16]	Curtis	[*Turns to Will and nods*] Yeah.
6		Will	So, Gary delegated it?
7		Curtis	He did. [*Laughing*]
8		Will	Oh man. [*Laughing*] **expletive** Gary
9	[00:04:21]	Curtis	No, he said I probably knew more about Excel and Word, anyway I'd probably get it done faster.
10		Will	You do. You have better computer skills than he does.
11		Curtis	How does that look? [*Looking back at his screen*]

12	[00:04:39]	Will	[*Leaning over Curtis's shoulder to look at screen*] That looks good… so… and then you are going to do like a rose underneath it that says ID::
13		Curtis	::Yeah
14		Will	::measure M1, 2. Ok. Cool.
15		Curtis	Yeah and then just fill it out.
16	[00:04:39]	Will	Beautiful. Done.
17	[00:04:42]		Don't let Gary take credit for it either, man.
18		Curtis	Yes sir.
19	[00:04:45]	Will	Credit… Credit is due where it belongs.

In this exchange, a mentorship interaction emerges without notice from an unexpected prompt. Although he is sitting two feet from Curtis, Will is unaware of what Curtis is working on until a noise draws his attention. Then he is surprised by Curtis's project and expresses some incredulity towards Curtis' role on the project. After prompting from Curtis, Will forms an *ad hoc* purpose for applying some mentorship and gives Curtis mild feedback, followed by light praise and work advice about taking credit where credit is due. This final piece of advice could be seen as attempting to provide a more experienced perspective on how one might navigate the engineering workforce as a social context—making sure you succeed by ensuring you receive the credit you are due. It is only at this point that the interaction moves from passive supervising to active mentoring.

We can also say something about the nature of Will's stance toward mentoring in this vignette. It would seem that Will was not actively positioning himself in a mentoring role until the need arose. The long pause Will takes between the giving praise and giving advice could suggest it is an afterthought. Furthermore, his cursing about Gary might suggest this advice reflects his frustrations with Gary more than a desire to mentor Curtis. The reasons behind this passive attitude toward Curtis is unclear, but we should point out that Curtis had only recently been moved under Will's supervision, so they might not have gotten to know one another. In fact, in later observations, Curtis reported that Will had taken a more active role and given him more responsibilities. Unfortunately, Curtis was laid off soon after these observations.

Overall, this vignette demonstrates that mentoring is often an emergent phenomenon based on prompts for the learner that are not actively sought out or anticipated. Furthermore, once the immediate need is addressed, the mentor's attitude returns to passive attentiveness. This highlights how mentorship can be fleeting.

Vignette 2

While such *ad hoc* and fleeting acts of mentorship are the most common, we still find many instances of direct, prolonged, and intentional instruction, such as in the following vignette. Here we once again find Will in the role of senior engineer. However, in this case, he is mentoring Hannah. Hannah is a recently graduated materials science engineer who, like Curtis, was hired on as a developmental engineer, but after less than a year on the job she was promoted to a full-time metallurgical engineer in the plant's melt shop. In this position, Will has been her direct supervisor and they developed a close working relationship. A cubicle wall separated their desks, yet throughout the day they talked back and forth with updates and questions about the current steel mixes and assuring quality control. Unlike the fleeting mentor relationship between Will and Curtis, Hannah and Will had a prolonged and active mentoring interaction. For example, one morning Hannah received a phone call from the hot rolling part of the plant (this is the second part of stainless steel production, in which slabs are rolled to be thinned and wrapped into coils) complaining that one of the slabs received from the melt shop had a crack in it. At this point, Will was not in the office, so Hannah was in the position of having to decide whether to try to grind the slab in the hope of salvaging it, or scrapping and costing the company money—a responsibility she normally would not have. After thinking it over, she says she is leaning towards scrapping the slab, but decides to wait for Will so that she can "get a good decision." When Will arrived, Hannah got his attention, which resulting in the following dialog:

Turn	Time	Speaker	Quote or [*action*]
1	[00:03:56]	Hannah	Um, we have a 439M in the furnace at **hot rolling** they're not charging it, it just missed the rounds because of cracks. This is::
2	[00:04:07]	Will	::of cracks?
3		Hannah	::Because of cracks. This is one of four that were in the slow cooling box…
4		Will	Yeah
5	[00:04:14]	Hannah	That the temp dropped below where it should have
6		Will	::And we moved them?
7		Hannah	::So my question is. Mm-hmm
8		Will	And now they have cracks?
9		Hannah	Yeah. So there's no point in even…
10		Will	Scrap it.
11	[00:04:20]	Hannah	J-Just scrap it?
12		Will	If it has cracks and we can confirm the cracks…
13		Hannah	They said it was all the way across… **hot rolling**… I haven't put my eyes on it, do I need to bring it here and put my eyes on it? Or…?
14		Will	Let's go over there and put eyes on it.
15		Hannah	Ok.
16		Will	If they can see it, we can see it, right?
17	[00:04:33]	Hannah	Sure… He was asking me what to do with it. I told him… He was gonna put it back in the furnace. I told him don't bury it because we are transporting all of our stuff, so I just need to have him sit it on the ground and let it go.

18 [00:04:46]		Will	Yeah. Yeah. Sit it on the ground, let’s go over and take a look at it and then scrap it if its got cracks.

In comparison to the interaction between Will and Curtis, this exchange is both more prolonged and more focused on a single task (thus, less prompted in the spur of the moment). There seems to be ample evidence here of accountable disciplinary knowledge. Hannah trusts her knowledge enough to use shorthand (e.g. “439M”—an international steel grade designation) without having to worry about being understood. The whole exchange shows a confidence and trust in one another’s knowledge base and understanding of the steel making process. Furthermore, Hannah is gaining knowledge about what level of defects that require grinding versus scraping, and that the trust in evaluating those defects should be engineers within her company and not another. At the same time, we would argue that there is evidence of a development of Hannah’s identity. In the beginning of the vignette, Hannah is presented with a problem that would usually be Will’s responsibility. She frets about whether or not to scrap the slab and decides to wait for Will. When Will arrives and they talk through the problem, he immediately comes to the same conclusion she had initially—that the slab should be scrapped. Then he backtracks and decides they should inspect it themselves. We argue that this acts to empower Hannah, as from that point on he does not hesitate to offer her opinions about what they should do. While this is a small change, we would argue that this slight boost in confidence and recognition of her authority is a part of her overall identification and development as an engineer, which is enabled by Will’s mentorship. Over the next several months of observations, Hannah’s confidence reached a point where she could run the metallurgical aspects of the melt shop while Will was out of town, and she even took charge of training and mentoring a summer co-op student.

Overall, this vignette demonstrates the less common but still present form of prolonged, direct mentor interaction between new and more senior engineers. It also shows how increased share of responsibilities in these interactions can result in the development of both knowledge and identity. In the previous two vignettes, each of the new engineers had a clear, single senior engineer who at times acted as a mentor—whether in the moment or over a prolonged period. The following two vignettes present a more complicated picture of mentorship, in which a new engineer lacks a clear idea of who, of many possible senior engineers, should fill a mentorship role.

Vignette 3

In this vignette, we will follow Ryan, who is a developmental electrical engineer. Ryan is in a somewhat unique position in that he had originally worked with Large Southern Steel Mill as a contract electrician, before being hired as an electrical technician, and finally being put in the developmental program as an electrical engineer. Being an electrical engineer in a large steel plant means that much of Ryan’s job is maintenance. As such, his job looks very different from day to day. In an interview with Ryan during our first week of observations, he expressed the problems with being a developmental engineer who is trying to gain knowledge, but without a clear mentor: “[An] electrical guy working for central maintenance, there's four electrical guys working there and they're always moving. They can't really ... I wouldn't say hold your hand, but they can't really slow down to explain one part of their project to you. That part of it on that side I didn't enjoy it. I was like, ‘This is a waste of time. They're going to cut this program.’” Here

Ryan reflects on the lack of a clear supervisor from whom he can learn. This is a theme Ryan returns to throughout this interview and during informal conversation: "What you're supposed to do is you're supposed to work under them, they're supposed to give you a senior engineer like I mentioned and you're supposed to start with small project and then they will teach you the area and how it operates… All that you're supposed to learn and I feel like a lot of this place is lacking in that area." Ryan's repeated use of the phrase "supposed to" suggests that something is being communicated to him that is not happening. This appears to be confusion about who his single main supervisor should be. Unlike, Hannah and Curtis, Ryan lacks a specific individual who is meant to act as a mentor.

This lack of obvious mentor has led Ryan to struggle to find projects, as no senior engineer is responsible for assigning projects to him. During our early observations, Ryan was working on small projects that he himself deems "busy work." These are projects that are low stake and on the periphery of central plant operations, and which Ryan can work on totally unsupervised. For example, Ryan had been tasked with building a trainer in an unused room in the melt shop. This trainer was a small scale mock-up of an electrical system that people could use to test wiring layouts without damaging equipment or causing shut downs. Ryan had been working on this project for weeks and continued to work on it over the course of our 5 months of observations. Unfortunately, no one had yet to use it. These sorts of projects may still be of use—being non-central does not mean they are not important or knowledge-rich.

Eventually, Ryan reached out to Jeremy, one of the senior electrical engineers in the melt shop to ask for a new project. This is something Ryan said he does when he feels like he does not have any substantial work. As it happened, Jeremy did have a brand new project, which he gave to Ryan. The new project involved the installation and wiring of a new kill switch in an electrical box in any area of the melt shop that had recently been flagged as a safety hazard. Ryan's assignment was to install a kill switch is this area that would allow operators in this area to disable the equipment that can normally only be disabled from a pulpit without view of the dangerous area.

Ryan moved quickly into this project. First, he went to the area deemed a hazard, took pictures of the setup, and documented the wiring. Then he then went to the electrical room from which the wiring for his switch would emanate and made diagrams of the breaker boxes. From there, he went to the control pulpit to talk to the operators to get more details on the system, the problem, and their preferences on how he might address it. Finally, he went back to his desk and pulled down the relevant wiring schematics and began working on his plan for the switch, the wiring route, and reaching the parts needed. The next day, however, the project hit its first snag. Jeremy told Ryan that another engineer pointed out that the kill switch would be considered safety equipment and thus the wiring must go through a different box exclusive to safety. Ryan brought out the schematics, and studied them for over an hour attempting to understand how to wire to this box. In fact, he realized that this area of the plant had no such safety box. After talking to Jeremy about this, it was decided that installing a safety relay in his switch system would meet the necessary safety protocols. After this conversation, Ryan set about making a diagram for his design, learning about the safety relays, and shopping for parts. Ryan even set up a plan to use the trainer he had been building to test the safety relay wiring. The next day, Ryan explained that after we had left our observations for the day, Jeremy informed him that the project had changed:

"Toward the end of the day [Jeremy] did tell me that he took his manager over there to show him the project… and um just like we were… when we were over there to the LTS, the ladle treat center [SIC], they were dropping stuff in there and it was splashing stuff out. So, immediately, they changed the entire project and they said that no longer will a simple switch setup work, that now they're going to have to do a complete gate around the entire area." In other words, the relatively simple switch installation in two days had become a major infrastructure safety project. At this point, Ryan's place on the project was unclear and he told the researcher: "I'm going to get with [Jeremy] later on today and see… uh… I guess… what I can help out on it."

In summary, after taking initiative, Ryan finally got a project that would help him learn in ways that he expressed he was "supposed to" as quoted earlier. After a day of working on it, the senior engineer changed the job and forced Ryan to scrap his previous work and go back to the drawing board on the project. After another day of work, management changed the project again to a level of complexity that removed it from Ryan's responsibility and left him unsure of his place on the project. Still, Ryan wanted the experience and said he wanted to find a way to stay on the project. Toward the end of the day, Ryan approached Jeremy and asked him for an update on the project, after which the following exchange occurred:

Turn	Time	Speaker	Quote or [*action*]
1	[00:00:06]	Jeremy	[*Pointing at computer screen he is seated in front of*] So that's what we're looking at total for the price. Five working days. 27 for two key entries, two door locks. But right now I'm sending out a quote to their competitors [*Glances at camera*] [[Name of installation company]]
2	[00:00:25]	Jeremy	Same set up, just different company. They tend to be a little bit cheaper. Still two normally closed contacts. Same thing.
3	[00:00:31]	Ryan	[*Standing behind and looking at Jeremy*] With this all new, are we, are we going to develop a lockout-tagout procedure?
4		Jeremy	[*Leaning back and turning to look at Ryan*] It already has a lockout-tagout procedure. [*Looks away from Ryan*] This is… uh… when you a… uh… [*Tilts head left to right*] When you do a entry system like this [*Looks back up to Ryan*] it is not intended as a lock out.
5	[00:00:48]	Ryan	Mm-hmm
6		Jeremy	[*Moves eyes up and away from Ryan*] It's to keep you… out of harms way, indirectly [*Looks back up to Ryan*]
7	[00:00:53]	Ryan	It's like the grinder keys they don't have to lock them…
8		Jeremy	Exactly. If they're in an area that there's a potential hazard, machinery operating, that's one thing, but if they're in direct harms way they need to be locked out.
9		Ryan	Mm-hmm

10	[00:01:09]	Jeremy	So, this isn't to replace a lock out. It's simply to restrict access to authorized people.

Ryan's goal in this interaction is to somehow remain a part of the project that has grown out of his reach. This is precisely the type of thing that has happened to him before and that he wants to avoid. He wants to be on a project where he can learn and grow. And yet, he begins his conversation by asking for more details about the new installation. Jeremy gives him a quick lesson on bidding out contracts (perhaps a mentoring tip on navigating the business), and Ryan then asks whether the new system will have a lockout-tagout procedure (this is a widely-used safety protocol that insures machines are properly shut off and not able to be restarted until the completion of maintenance). However, Ryan already knew the answer to this question. Earlier in the day, when Ryan told the researcher about the new gate install, the researcher asked Ryan if it was like a lockout-tagout, and Ryan told him it was a different procedure that limits access, which is nearly identical to Jeremy's answer to Ryan. In fact, several of the questions Ryan asked seemed to be things he already knew. Take the continuation of the previous exchange:

Turn	Time	Speaker	Quote or [*action*]
1	[00:01:09]	Ryan	Okay
2		Jeremy	And have the machine in a safe state when they're passing through the area.
3		Ryan	Okay. But then is it going to be kind of like the grinder where the operator upstairs has to release the key?
4		Jeremy	Uh, no, we'll put a local entry, so when the stirring system is off they're allowed access. If it is on, they can't get access.
5	[00:01:25]	Ryan	Ok. So, they just walk down to the gate. The can turn off [*Gestures with his hand the pulling of a switch*] the access. Pull the key [*Mimics pulling a key out of a lock*]. Open the gate.
6		Jeremy.	Mm-hmm. That's right. They'll have a 22-millimeter push button to open it… to remove the key, then they can go through the gate. If the stirrings already active… that button all it does is energize a solenoid. To release the key… and if stirrings active there will be no output for the solenoid so they can't release the key.
7	[00:01:44]	Ryan	Okay.
8		Jeremy	So it is just a way to restrict access if the equipment is in operation. But… um
9		Ryan	Before you couldn't bypass while it was in operation anyways, right?
10		Jeremy	[*His eyes look straight, his lips tighten and after a moment he shakes his head*] Yes.
11		Ryan	You could?
12		Jeremy	That's why we're doing this, because could turn the

			bypass on and it's a potential hazard because it is full line pressure. 800 liters per minute. So…
13	[00:02:03]	Ryan	And they shouldn't be down there when you're bypassing anyway.
14		Jeremy	Uh huh. No. And that's why it's a potential hazard because it is so much ff… so much pressure, so much flow so fast that there is potential for splash out.
15		Ryan	Mm hmm
16		Jeremy	They need to have some way to not… to have access restricted during that time. If it does. It happens. It's a bad situation, but if no one is down there we will recover from it. You know?
17		Ryan	Mm hmm
18	[00:02:25]	Jeremy	Main thing is just to protect them.

In this exchange, Ryan asks a series of questions in order to elicit more information and feedback from Jeremy. Again, many of his questions seem to be about things he already has the answer for. For example, Ryan asks if before operators were about to use the bypass while the machine was in operation. This was part of the problem his switch was meant to fix, so surely he knew this. What is he doing here? We argue that Ryan is engaging in some navigation towards his goal. He is keeping Jeremy in conversation by asking questions he knows, in order to follow-up with either more questions or chances to demonstrate his worth. This strategy of trying out assessments, descriptions, analogies, judgments, and questions to garner attention and feedback seems to be an important way for more junior engineers to actively elicit mentorship from more senior engineers.

Ultimately, Ryan engages Jeremy long enough to ask to remain to be on the project. And even this request demonstrates Ryan's ability to navigate his more experienced coworkers. The following exchanges take off from where the previous left off:

Turn	Time	Speaker	Quote or [*action*]
1	[00:02:28]	Ryan	So I know this project escalated very quickly and now it turned very advanced, but what can I help out with that won't slow you down?
2	[00:02:35]	Jeremy	Umm… What we need to do…
3	[00:02:39]	Ryan	Or I could just shadow you…
4		Jeremy	Probably shadow me a little bit because day of will be doing this… typical outage is 2 to 3 days and there is two, two completely separate systems that's got to be done. So you can start on one and I'll do the other… at the time… I only have two electricians, so I'll put one with each and if you are up to speed on everything… by that time working with me on it then we be able to back and forth whichever…

5	[00:03:04]	Ryan	I was going to say, if I can get documentation I will go scan it real quick and get up to speed.
6		Jeremy	Sure [*Starts grabbing paperwork for Ryan and inaudibly points out what each paper is. Ryan picks them up*]
7	[00:03:43]	Jeremy	But as it goes along, I'm sure I'll break you off and say handle this part, handle that part while I'm doing something else, but for right now we can stay together on it to where you get… Like I said, day off you can do one side, I'll do the other.
8		Ryan	Mm hmm. Okay
9	[00:03:59]		[*Both nod heads in agreement*]

In this interaction, rather than bluntly asking to stay on the job, Ryan first acknowledges that the project is now beyond his expertise and then frames his request as an offer to help Jeremy while assuring him he will not interfere with or slow down the work. This is actually a fairly sophisticated bit of persuasive communication and it seems to work. Jeremy offers Ryan the opportunity to shadow him and develop his skills to a point were he will be in charge of one of the installs when the time arrives. Ryan returned to his desk and began studying the new project plans, seemingly believing he had landed the mentor from whom he hoped to learn and grow as an engineer.

Unfortunately, this story does not end the way Ryan hoped. On our next field visit, we asked Ryan how the project was going. Ryan told the researcher that when he returned from the weekend, he went to talk to Jeremy about shadowing him. Jeremy told him he would get back to him, but after three days he had not. So, Ryan went to Jeremy's desk and asked again, but was not given an answer about the project. He said he tried contacting Jeremy one more time, and after Jeremy again ignored him, he moved on to different projects (or returned to his old ones). We asked if the install had happened or if it had just been postponed. He said he didn't know, so we decided to walk to the ladle treatment station to see for ourselves. The installation of the gate and lock system had been completed weeks before, without Ryan's involvement.

As viewed in the vignette, Ryan's struggle to find active mentorship reflects many of the difficulties faced by new engineers when starting a new job and being confronted with aspects of the engineering workforce for which they have not been prepared. This is an especially good example of the lack of knowledge of hierarchies and the differences a clear chain of command can make. It is easy to blame Jeremy for failing to mentor Ryan—of course, he likely could have been more forthright—but Jeremy had a time sensitive project and he is paid to complete these projects, not to act as a teacher for a young engineer. The truth is, new engineers will face many hurdles beyond mere knowledge of their field and they must be prepared to navigate stakeholders, constraints, and politics present in any workplace. So, while Ryan demonstrated fairly well formed navigation skills he was not able prove himself valuable enough for Jeremy to keep him on the project. This seems to be a common occurrence when the need to complete work takes precedence over the need to train new engineers and they get cut out.

Overall, this vignette demonstrates how a lack of a clear, single mentor figure can cause confusion and result in a new engineer struggling to find training. Furthermore, this vignette highlights that rather than just gaining experience and knowledge, the development of new engineers also requires learning skills to help them gain trust and establish themselves with more senior engineers and their company, in order to gather more responsibilities.

Vignette 4

In our final vignette, we continue with observations of Ryan and how they evolved over the months following the previous vignette, in particular how a different senior engineer stepped in as a mentor. A month after the events in vignette 3, we returned to the Large Southern Steel Mill to resume observations. It was at this point that we learned about Ryan having not been a part of the gate and lock installation. This obviously was a frustration for him, but even more than that, a week prior to our visit many employees at the mill had been laid off (including Curtis). Ryan had been told he was not being laid off, but at this point it was unclear whether he would be promoted to full electrical engineer or demoted back to technician. In any case, Ryan was uneasy and feeling somewhat antagonistic toward the company—expressing that he “doesn’t trust” the company. Shortly after we got back from visiting the hazardous area from the previous vignette to see if the gate and lock had been installed, a senior electrical engineer named Tom came to Ryan’s desk and told him that one of the cranes in the scrap yard had shut down and he needed his help.

A group of operators were all working on the crane, but when Tom arrived he took a supervisory role. It was clear that he was in charge of the situation as he directed everyone’s efforts. In particular, he had a habit of asking questions during the troubleshooting process rather than telling people what to do. (We should note that the crane was small, cramped with people who had not been consented to be recorded, and was very loud, so this data comes from written notes.) He frequently praised Ryan to other workers; even telling them that Ryan was an expert with the energy analyzer being used to diagnose the crane’s electrical problems. The fix of the crane took all day, so the following day we were able to ask Ryan about Tom. Tom was a plant-wide engineer, so did not spend all of his time in the melt shop, like Jeremy. Ryan said that he had known Tom since he began, as he had purchased all of the developmental engineers copies of two books on communication and accountability in the workplace—the books being Patterson, et al., (2011) and Patterson, et al., (2013). Ryan said Tom had occasionally given him projects or asked him about other projects he was working on.

Eventually, we were able to talk to Tom about how he worked with Ryan and others. We asked him why he seemed to take on a more active training role than others. He explained that this comes from his experience in the military. He said that when you are promoted in the military you go through training about how to lead, but in the civilian world people are promoted without knowing how to train others, which he claims makes everyone look bad: “As an engineer, one of the most important things to do is train other people, bring other people along. Also, my success is determined by them, whether or not they want to see me successful.” This is also the reason he gave all of the developmental engineers books: “As an engineer, it's important that you know how to communicate with other people in an effective manner that isn't condescending, that's on target.” Obviously, this is a much more active from of mentoring then either Will or Jeremy displayed, yet Tom was not Ryan’s direct supervisor, so their interactions had remained infrequent.

On our third week of field visits, a month after the crane observations, we learned that Ryan was no longer a developmental engineer and had been promoted to full electrical engineer. If you recall, the developmental engineers were assigned to specific areas of the plant and then rotated after several weeks. This means that during all previous observations, Ryan was confined to the melt shop. However, this promotion freed him to take projects anywhere in the plant. We also learned that Tom had given Ryan a major project, on which he was expected to be lead engineer. In this project, the finishing plant (the last part of stainless steel making, in which the steel is spun into customer-specific coils) was installing two automated wrapping machines to wrap the final coils for delivery. Ryan was charged with designing the wiring schematics for the full power distribution for each machine, as well as overseeing the contractors' installation of the power distribution. To begin the project, Ryan walked around other parts of the plant to find other power distribution units and take notes about their setup, the breakers used and how many, the placement of various parts of the system, and how the conduit was run. He then went to finishing and took notes about where the power distribution would be installed and how he might run wire. With all of this research together, Ryan began drawing up preliminary plans and a parts list. A few days later, Tom asked for Ryan to accompany him to finishing to finalize the plans before making the project's scope form. While walking through finishing, Tom and Ryan talked over Ryan's initial plans. Tom frequently provided advice on technical issues or other accountable disciplinary knowledge. For example, when discussing whether to put specs or part numbers in the scope, Tom said: "You are better off using part numbers, because that way you know what you are getting. And when picking a part number, if at all possible, pick a part number that already exists on the plant." However, as Tom and Ryan approached Dante (the lead engineer of the finishing plant who had to give the go ahead on all plans), Tom mentored Ryan on how to communicate, such as in the following exchange:

Turn	Time	Speaker	Quote or [*action*]
1	[00:04:44]	Tom	And also you don't want to get yourself... You don't want to create the habit where you say respond by email that you concur with this... in other words you're telling them "I want to be able to blame you is nothing goes right." Instead just say "hey here's what I'm gonna do and I just and… Here's what I'm planning on doing" and just talk to them face to face... "Are you good with it?" Because what that does is helps you create an environment where people will like working with you. Because once he says he's good with it... he's fine. He doesn't feel like you're trying to bury the hatchet in his ass or something.
2	[00:05:29]	Ryan	Okay. Be a little more discreet when we try to do that? [*Smiles*]
3	[00:05:39]	Tom	Yeah. Still hold his feet to the fire hey you told him... A lot of people will never respond to your emails you know you're gonna use that as a legal document... you want people to respond without a fear that you're

a prick

Here Tom is explicitly giving Ryan advice on how to talk to other engineers in a way that makes him seem trustworthy, while still holding other engineers accountable. Tom has entrusted Ryan with new responsibilities for this project and if Ryan fails then Tom, as senior engineer, will still likely take some blame. Therefore, by giving Ryan this advice, Tom seems to be acting out his "my success is determined by them" philosophy that he expressed in our earlier interview. Furthermore, the content of this advice—dealing with other engineers to gain trust—is a direct mentoring of Ryan's ability to navigate the engineering workplace. Tom takes this lesson even further. When Tom and Ryan talk to Dante about finalizing the scope, Tom models the behavior he had just advised to Ryan. When Tom talks to Dante he first explains the plan Ryan has and then uses phrases like, "Tell us what you want." "Are you happy with [that]? Or do you want [something else]?" And "That's fine?" This is very similar to the "here's what I'm planning on doing… are you good with it" phrasing that Tom advised in the above exchange. Here Tom is advising behavior and then modeling it, in order to demonstrate the utility of his advice.

In the remainder of this observation, Ryan worked on putting together the scope. Ryan had no experience writing a scope and worried he would make an error. Tom advised that he "put 20% effort into it" and then they could look at it together. This seemed to calm Ryan enough that he put the scope together by the end of the day. Tom told him he did a "damn good job" and offered minor changes. Ryan told us that he was going to use the praise "for fuel to motivate me on the next project." By the time, our next field visit came around a month later, the wrapping machine project was complete and Ryan had supervised the installation without Tom being present.

Of course, this is still only one fully successful project for Ryan in many the months of our observations. In fact during one of the last conversations Ryan had before our observations ended he expressed the same frustrations he had at the beginning of our study. When talking about finding projects, Ryan said:

> "I don't know, man, I just don't want them ... I know I'm supposed to take initiative, I'm supposed to find my own projects, but it doesn't make sense that every area has an area engineer that has their own projects. How am I supposed to go out and find my own project? You know? Not only do I have to find my project, I have to step over the area engineer who's over that, and I have to get them to tell me that I can work on their line on that project. Then I have to talk to the manager over that area and get them to justify the project that I have, he will allocate me money to spend on this project. You know? It's kind of like, I believe in chain of command, I was never in the military [or] nothing, but of course, my manager and another manager. I just don't understand how I can step over everyone and find my own project. You know what I mean?"

Overall, this vignette demonstrates the importance of senior engineers who are not only willing to take the time to mentor, but also put the effort into understanding how best to mentor. Even if ultimately Ryan's experience is overall frustrating. This vignette suggests a fully engaged and successful example of mentoring of new engineers in the workforce. Tom's mentoring is active, thoughtful, and prepared and stands in contrast to the fleeting mentorship we saw earlier. Like

Will was with Curtis and Hannah, Tom is a single source Ryan can turn to for guidance. However, there were clear hierarchies; Tom was definitely the “teacher” to Ryan’s “learner,” unlike the more hierarchically even relationship between Will and Hannah. (Will was obviously more senior, but responsibilities were shared between the two). In any case, this relationship and its successful mentoring is a stark contrast between that of Jeremy and Ryan.

Discussion

The vignettes collected above are meant to provide a snapshot of the current state of mentorship for new engineers in the modern workforce. As such, we tried to provide a balance between the depth and breadth of our portrayal. By narrowing our scope to describe a few individual instances of mentorship we obviously miss whole relationships between any pair new and more senior engineer over longer periods of time. By providing examples of multiple relationships with one new engineer (Ryan with Jeremy and Tom) and one senior engineer (Will with Curtis and Hannah), we hoped to overcome some of the lack of depth that a full case study could provide.

Overall, the findings provided here still are able to characterize some things about modern engineering mentorship. First of all, mentoring is often fleeting and prompted by in the moment needs rather than a senior engineer’s active efforts to mentor. Many examples of mentoring we find are spur of the moment and lack planning. This often results in surface level assistance that may or may not be of any help. Second of all, there are still opportunities for active and prolonged mentorship, but it requires effort on the part of both parties. Furthermore, this active mentorship is most frequently in relationships where hierarchy breaks down and responsibilities are shared. That said, there are examples, like that of Tom, where active mentorship can occur despite fairly rigid hierarchies. Third, the existence of mentorship is determined by institutional constants and the motivations of both learner and mentor. For example, the nature of the work culture for electrical engineers in Large Southern Steel Mill leads to Ryan having no clear senior engineer from whom to be assigned projects. Instead, he was meant to seek out projects from many different engineers, leading to confusion. Furthermore, there must be a desire from both parties to engage in mentoring. Likewise, institutions must provide such opportunities. For example, Large Southern Steel Mill created a developmental engineering position in the hopes of training and mentoring young engineers; however, they failed to offer resources (training, time, incentives, etc.) to encourage and aid senior engineers in providing that mentorship. Finally, mentorship is heterogenetic within organizations or individuals. In the vignettes above we saw several forms of mentorship within a single company and for individuals—both mentors and learners—over time. Those forms included in the moment problem solving and advice giving, prolonged shared work, fleeting instructions with no follow through, and planned, direct teaching. The modern workplace is complex and shifting, so we would expect mentorship to be as well.

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