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Learning to Anticipate the User in Professional Engineering Work

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Introduction

Who are the users of a product and how do designers, including engineers, figure out who their users are and how they should design to respond to their needs? Far from being an abstract question, this problem motivates engineering design—the application of science to real-world problems. When done in the workplace, figuring out who users are and how they will use products has a notable learning component. Experienced engineers working with new products may be working with unfamiliar users, while early career engineers are learning that end users are important to anticipate during the design, testing and implementation process.

Studies of engineering work, workplace learning and science and technology studies have historically observed these design and work practices in order to better understand the relationships between technologies and users. This focus has generated a diverse number of concepts that describe users and the “user-technology nexus” (Oudshoorn & Pinch 2003:2). One major contribution of these approaches is to conceptualize users and technologies as co-constructed; technologies contain the parameters of their own use, but users can also employ technologies in unexpected ways. Moreover, perceptions of users influence how designers make new technologies, implicating users in the design process far before testing and implementation. Importantly, the design of a product or technology can shape the possibilities for how users can interact with it. Especially as scholarship has shifted to recognize that users engage actively with products as opposed to passively receiving them (Oudshoorn & Pinch 2003), it has become possible to conceptualize the ways in which designers develop technologies with the aim of ‘configuring’ or shaping users’ actions (Woolgar 1990, Akrich & Latour 1992) and to analyze the downstream effects of technologies on unknown or silent users (Casper & Clarke 1998). These efforts can also be understood as a way of organizing others’ work (Suchman 2000), particularly when the users come from inside one’s own organization.

In this paper we describe and analyze how early career engineers learn about users and their needs in the engineering workplace. We draw special attention to how users are conceptualized during product development and how notions of how users might employ technologies can shape designers’ plans. These data are part of a larger project that examines the workplace learning of early career engineers, and so several of our examples highlight the orientations early career engineers hold toward users and how these orientations are calibrated by more experienced engineers in the workplace. Indeed, designing a technology for future use implies knowledge of or anticipation of the end user. We therefore investigated how early career engineers learned about the users of their products. We find that engineers of all levels learn about users so that they can design for their needs through a range of activities: translating information for non-specialist audiences, highlighting salient information to direct users’ attention, implementing systems that control the work of others, and creating engineering products free of idiosyncrasies that can be interpreted by a range of users. This emphasis on workplace learning and the social aspects of design reinforces efforts to represent engineering simultaneously a social and technical (or *socio-technical*) form of work (Suchman 2000; Stevens, Johri & O’Connor 2013; see also

Adams, Evangelou, English, Dias de Figueiredo, Mousoulides, Pawley, Schifellite, Stevens, Svinicki, Martin Trenor & Wilson 2011 for a discussion of socio-technical engineering) and has implications for engineering educators that we will address during the discussion.

We take a broad perspective on what may be considered a technology and who may be considered a user. In the analysis, we cite examples of engineers making a matrix to organize relevant ordering, sales and product documents for a diverse set of employees to reference when interacting with customers and assembling product orders. We also examine the efforts of engineers at a supply chain management company to increase the efficiency of their warehouses by closely controlling the forklift operators who load, unload, and transport goods. We also note the attention that engineers, particularly early career engineers, devote to the aesthetic elements of product design—as we show, this can function to draw users in, or alternately, to disguise the engineer's mark on the final product, rendering it widely usable.

Methods & Data

These data come from a broader National Science Foundation-funded investigation of the school-to-work transition of early career engineers in which we focus on workplace learning to examine areas of mismatch between the skills taught in engineering undergraduate programs and the skills required for success in the workplace (Vinson & Stevens 2016, Stevens & Vinson 2016, Stevens, Johri & O'Connor 2013). This study was motivated by a general lack of ethnographic studies of this transition period, and by a growing consensus among engineering education stakeholders that knowing more about the daily working conditions of early career engineers would help engineering educators as they design their programs. Broadly, the study is motivated by the question: what do early career engineers learn at work and how do they learn it? To answer this question, we employed an approach called *person-centered ethnography* (Hollan and Wellenkamp, 1993; LeVine, 1982, Stevens, O'Connor, & Garrison, 2005) that allowed us to focus on early career engineers and how they were shaped by the context they were embedded in.

Over the course of a year our team interviewed early career engineers about their work and observed them in the workplace (N=20). We conducted workplace observations in five field sites: a large integrated steel mill, a small medical device testing company, a small research and development firm for containerless processing, a supply chain management company, and a corporation specializing in the design, sale and installation of elevators. Participants were recruited either through their companies or through the university they graduated from (Stevens & Vinson 2016). The data collection was conducted by Vinson and Davis using ethnographic methods including participant observation, videotaping work activities, semi-structured interviews, and field interviews. The data were coded thematically using content logging software and qualitative data analysis software. The analysis follows the interpretive tradition of ethnography, where the researcher's understanding of the phenomena is enhanced by her/his presence in the situation and knowledge of the participant and work environment. Ethnographic methods were a good fit for addressing our research question because they allowed our researchers prolonged access to each field site and gave us the opportunity to directly observe the same engineers in a variety of different situations.

In this paper, we draw on ethnographic observations of and interviews with some of these early career engineers as they participate in and reflect upon product design, process testing, data presentation, and workflow planning. Our objective is to show how engineers conceptualize the users of their products and take them into account during the design process. Our analysis follows these engineers as they produce documents, drawings and presentations and highlights the role of more senior engineers who provide feedback and corrections to help the new engineers understand who the user of the product will be, what the user expects from the product, and how the company would like the user to behave.

Findings

We found that engineers anticipate the user of the products and systems they design and that learning about the company's end users is an important professional task for early career engineers. Engineers anticipate the user in two ways: by learning who their user is and designing to meet their needs, and by designing systems that control/configure the user (based on their estimation of how the user will or should behave). Because theoretical work on configuring the user highlights not only needing to know about the user in order to design, but also examines how technology can be used to constrain users' actions, we provide one example of each process. In the final section of the findings, we draw attention to the aesthetic elements of design that engineers attend to when trying to engage the user or cover the tracks of the designer. This has not previously been addressed as an aspect of user design within science and technology studies, offering a contribution to theory on configuring the user. Throughout the findings and in the discussion, we describe ways that our findings may benefit engineering educators.

I. Learning About Users During the Design Process

The Innovations Team at International Elevator Corporation works with new product lines and products in development, but they also communicate with other parts of the supply chain and sales team to help design, source, test, sell, and provide installation support for the company's products. Priya, an early career engineer who had recently been transferred to the Innovations Team, had a varied workload; she worked with several different product lines at different points in the development process. She brought to the team her expertise in one of the product lines, a card-activated elevator system, and was building her expertise in other products in development, while learning the ins and outs of the older elevator systems.

During one observation session, Priya explained that she was making a matrix in Excel that organized all of the documentation for each product line across all of the stages of the sales and installation process. Her supervisor Gabriel had assigned this project to her, and she was also getting assistance from Jed, another team member. Most of the actual work of making the matrix was finding the forms that corresponded to each stage of the sales and installation process for each system. This required familiarity with the range of forms necessary for each stage in the process, as well as acquaintance with the online document database. As Priya located the relevant forms, she added the file name to the matrix. As she filled in the matrix, she began to reorganize the column headers; making the matrix itself prompted her to rethink her organization of the information. She also began to format her spreadsheet, enclosing row and column headers with thick box outlines and enlarging the fonts of the column and row headings. She also color-coded the columns so that it would be obvious that the spreadsheet organized information for each product line (column) at each stage of the sales/installation process (row).

Near the end of the first day, she emailed the most current version of the matrix to Gabriel. Almost immediately he came by to ask Priya to schedule a meeting with him and Jed for later in the week so that they could all go over it together. As she was scheduling the meeting, she got Jed's attention and asked him if he would fill in the remaining columns in the matrix because he knew more about those product lines. Jed turned around and caught a glimpse of Priya's brightly colored spreadsheet. His eyes widened and he looked both surprised and amused at the assortment of colors in her spreadsheet (from left to right, she colored the columns brick red, bright yellow, robin's egg blue, mustard yellow, moss green, bubblegum pink, and salmon pink). He asked Priya to post the matrix on the shared online workspace and he would send her the information she needed to fill in the rest of the sheet.

The next morning Gabriel engaged Priya in a conversation about the matrix. He began by telling her that it looked good. "Really colorful, right?" she replied. He asked her to add other columns to it to reorganize it by platform (product offering) rather than by project, as she had originally organized it. Priya explained that if people want to order a product, then this sheet tells them what to refer to. "They're not going to say, I want to order a [hybrid system]," she said. Gabriel agreed, but explained that he had another organizational framework in mind. He added grey bars that organized columns into two super groups matching two different attributes of their innovative elevator products. In a lengthy conversation that also involved Jed, Gabriel explained that this was a prompt sheet for the front-line people (who would be most concerned about the initial steps in the process—ordering, tendering, etc.), the supply line people (who would be most concerned with the final steps in the process—installation, handover, maintenance, etc.), and the supply line managers (who would be concerned with every step in the process). He said that putting all of this information in one place would help them be more independent—he said that right now sales representatives were picking up the phone to get answers from others instead of trying to find the information themselves. In this conversation, Gabriel began orienting Priya to the larger purpose behind the task. While she seemed to be generally aware that this document would be used by others to locate relevant documents for ordering and assembly, it seemed that it was not until this conversation that she understood the specific circumstances that had prompted Gabriel to have her design this matrix.

While he looking at the matrix with Priya, Gabriel changed one column heading to "Innovative Product Offerings." As encouragement to Priya, Gabriel said he was excited about the matrix and gave Priya two brochures to help her learn about how some of the product lines looked on the sales side. Priya said that she liked how colorful the sheet was and that she thought it would make people want to engage with the content--"it will make people *want* to read it!," she exclaimed. Gabriel also asked Jed to share a spreadsheet with Priya so that she would be able to fill in more information for the new product categories Gabriel had just added to the sheet.

This additional input from Gabriel and Jed prompted Priya to reconsider her current organization of the matrix, including her color-coding system. Because Gabriel had added a new column for a multi-product line, Priya had to figure out how to break this down into the three different versions of the product. She settled on three columns that were all grey colored. As she worked, she was simultaneously reorganizing the content and using aesthetic cues to indicate how information was organized. As she was working, Priya said to herself, "change the yellow." The research team member, Vinson, replied “change the color?” Priya replied, “I like yellow, but it’s really bright.” She changed the color of the column from yellow to periwinkle blue.

The following day was Wednesday, when Gabriel, Priya and Jed had planned to go over the matrix together. Gabriel and Priya went into a small conference room and Jed joined via Skype. Gabriel began the meeting by reviewing the purpose of the matrix. He explained that new employees were joining the company in different departments, and that having all of the resources necessary for every step of the sales, order, assembly, and delivery process would help the new employees, but it would also help their Innovative Products Team identify any gaps they have in documentation and resources.

Gabriel began by looking at the rows of the matrix, which were labeled to represent stages in the sales, order, assembly, and delivery process. He suggested one minor change before moving on to the organization of the columns. Each column represented a product line, and over the past couple of days the discussion of what product lines would get their own column and how columns would be grouped under superheaders had characterized Gabriel’s guidance to Priya. Because they had already discussed the column structure, they did not spend too much more time on this.

Gabriel turned the discussion to looking at the individual cells of the matrix. One point of discussion was whether the order forms should be listed in the Sales row or in the Order row. Gabriel said they should leave the order forms in Sales because the sales people will only want to look at the sales category of the matrix. But he later changed his mind to have the order forms in the Order section, “just to be consistent.” Priya replied, “I agree. That was my point.” Gabriel pointed out that “sales will be proactive and looking to ordering [the Order category].” But then he pointed out that “the front line in North Americas is like care sales. In [the company’s Global division] they have more technical expertise and jump straight to the order form—so for [a specific Global product offering], leave the order form in Sales.” Gabriel explained that Global sales representatives would jump to the order form, but North America sales representatives would divert customers to an Ordering department for ordering—sales and ordering is more separate in North America because the sales representatives do not have the technical expertise that the Global sales team does. In this conversation, Priya wanted to keep the order forms in the order category because she was interested in making sure that the content in each row was consistent across the columns. However, Gabriel articulated a different rationale for categorizing order forms, and that was related to his knowledge of who would be doing the sales and what their level of technical expertise was in contrast to the level of technical expertise that would be required for doing the ordering—and how that varied by sales region.

As Gabriel continued to request changes to the matrix, which was projected on a shared, wall-mounted monitor, Priya typed them in. She was attempting to maintain her existing formatting by making the content change and then the formatting change. Gabriel discouraged her from doing this, saying “Just copy/paste—you can format later” and “We can make it pretty. We can do that later.” While Priya’s priorities were simultaneously content-based and aesthetic, Gabriel was primarily focused on content and content organization. Gabriel also justified his changes to her organizational structure by reminding her about the upcoming product developments in the company and how the company's long-range vision integrated with the current product line.

This example demonstrates that engineers design products to direct users' attention. For example, during the team's discussions Gabriel and Priya each experimented with different column and row headers. While row headers denote specific stages in the sales process, they also describe different user groups that work with customers and customer orders at different stages in the process. Misnaming a row could mean that the existing front-line and assembly personnel could not use the matrix to aid their work because they would not be able to find the documents that they need or that they might overlook important documents. In a case like this, the document matrix's purpose as a work organization tool would fail.

This example also serves as an example of how early career engineers learn who their stakeholders are and what the stakeholders' needs are from more experienced engineers in the workplace. In this example, all of the engineers were concerned with the presentation of content in the matrix, but they had different priorities and different ideas about how content should be organized. As the team leader, Gabriel made most of the final decisions, although he outsourced the legwork of the project to Priya and kept Jed in a mid-level advisory role to her. Priya brought up important content organizational considerations, such as the fact that organizing the material by product line obscured the fact that some product lines could have add-on components that weren't currently indicated in this spreadsheet, such as optional mechanisms that could be used to customize several different types of elevators. She also displayed significant expertise with a new product that Gabriel and Jed were not as familiar with. Gabriel let her speak freely on areas of expertise, but also directed her attention to the bigger picture by reminding her that this document will evolve as the company adds more offerings. He also helped her focus on the organization of the raw content, making it clear that the overall appearance of the spreadsheet was important, but that it could be polished after the meeting was over.

Gabriel continually emphasized who the users of the matrix were going to be, as well as meaningful differences between groups of users (such as the Global sales team and the North Americas sales team). Through his guidance, Priya was able to learn about other product stakeholders and how to present information to meet their needs. This example demonstrates that the process of learning about stakeholders and stakeholder needs is socially mediated; through feedback, more experienced engineers instruct early career engineers how to present information in ways that meet stakeholder needs, thereby explaining who the stakeholders are and what they are like.

Whereas Priya was able to learn about the various users of the document matrix she was developing through working with Gabriel and Jed, other early career engineers enter systems where the users are much more obvious. In the next example, Margaret and Chris, both early career engineers, learn about their roles in the engineering department of a supply chain management company that employs technology to control floor-level workers to meet the financial aim of efficient warehouse management.

II. Controlling Users with Technology

The engineering department at Supply Chain Management Company coordinates and analyzes the flow of goods into, out of, and through the company's warehouses. Their goal is to optimize the intake and storage of goods, as well as optimize the process of shipping goods back out. Whereas goods are brought into the warehouse on one-product pallets (a whole pallet of canned beans, for example), pallets often leave the warehouse stacked with a variety of different products to fulfil customer orders. A fleet of forklift operators transports loaded pallets around the warehouse and stacks products on empty pallets to ship out to retailers.

In order to encourage efficiency and ensure productivity among the forklift operators, Supply Chain Management Company implemented an incentive system for operators. As they move pallets through the warehouse, forklift operators are constantly scanning barcodes on door jambs and aisle markers. In designing the incentive system, the engineers designated travel times for each distance/path in the warehouse and associated this with the barcode scanner of each forklift operator. When they complete their transport within the specified time, forklift operators qualify for an incentive. By associating discrete time values with each travel path, engineers are able to quantify how long the work should take, and by extension, how much it should cost. This allows them to estimate and track labor costs, as well as estimate the costs of inefficiency (for example, missing a shipment deadline because the pallets were slow to be put together or loaded in the tractor trailers). In this way, the engineering department remotely controls the ways their forklift operators can *use* the warehouse as they conduct their work.

Interestingly, forklift operators are able to repurpose the engineers' system for their own gain. This reflects Oudshoorn & Pinch's (2003) description of how existing technologies can be used for unanticipated purposes. For example, Margaret explained that sometimes operators drive the same pallet around and scan it in at different locations. However, when this happens, incentive numbers will be drastically inflated, which prompts the engineers to look more closely at the record of scans. Margaret explained that operators get a series of warnings by offense: "verbal, written, you're done." In their everyday work, Supply Chain Management Co. engineers were frequently engaged in tasks to modify the incentive system, monitor incentive payments, and work with warehouse managers to train the forklift operators to work in line with the engineers' work process design. One way to understand the constant monitoring and modification of the incentive system is that the relationship between the users and the designers is always in flux.

This dynamic relationship, characterized by a struggle over who controls the work of the operators and the use of the warehouse, is also present in the packing and shipping process. When it is time to ship goods out to retailers, each pallet's load is also put together by a forklift operator. There are limits on the automation of this process; it often takes a human worker to arrange boxes of different sizes into the layers of the pallet—boxes must be laid in the shape of a square, but not every order calls for enough boxes to make a complete layer. The engineers seek to optimize the flow of forklift operators and goods throughout the warehouse so that the travel time for each pallet is reduced and the outgoing pallets can be put together quickly and logically (heavy/bulky items on the bottom, fragile/lighter items on top). The engineers aid this process by generating a list of frequently shipped products that warehouse managers can group in a separate priority aisle so that forklift operators do not have to travel far to compose custom pallets to meet customer orders. Engineers can also strategically place products in different bays along the aisle to influence the path of the forklift operators, as well as designate which direction forklift operators enter/exit the aisle by placing empty pallets at one end and giant pallet wrapping machines at the other. They also provide a list of products that forklift operators should put on each pallet that is ordered to follow stacking guidelines established by the engineering department.

However, despite their detailed efforts to shape how forklift operators use the warehouse and forklift technology to maximize efficiency and profit, Supply Chain Management Company had been experiencing problems with how the operators build the pallets. At one meeting, the engineering leadership debuted a new voice activated software program that would give verbal commands to the forklift operator as s/he completed tasks. This was particularly designed to solve the problems of pallet composition. As one engineer explained, simply providing operators with a list of products to be placed on each pallet had left them with too much control, and the operators had begun to assemble pallets in ways that were convenient for them as they moved down the priority packing aisle. Other engineers cited examples of operators who discovered that a product had not been replenished in the priority bay on the packing aisle, and rather than getting more of it from a remote location, had just skipped putting it on the pallet altogether. One department leader commented, “Our people want to be artists out there. They think they know best and God bless them.” The engineer who was explaining the software agreed, “Sometimes they do know best, but most of the time…no.” This engineer described the system: “It takes control away from the [operators]” because it tells them which items to pick and forces them to do it in a set order. In order to use the system, the forklift operators wear a headset with a microphone. They receive a command and can also interact with the software using a set of verbal commands. When using the new software, the operators are unable to exercise choice when assembling pallets because they only have access to the immediate next item to be put onto the pallet.

Engineers noted a few other advantages of the software in addition to increasing engineers’ control over the packing order. One engineer pointed out that this has had the unexpected benefit of making the operators unable to chat with their friends while they are working. One department leader also mentioned that the voice command for the next pallet can be given while the operator is still assembling the previous quantity of boxes onto the pallet; introducing this type of simultaneity could reduce the overall time that operators spent assembling pallets, thereby increasing efficiency. Department leadership was very enthusiastic about this new product because it offered benefits for controlling the forklift operators, a workforce that was sometimes characterized as difficult to work with because of low educational level and high turnover. Although this software would increase surveillance of the operators over and above the existing travel time incentive system, the group did resist some engineers’ suggestions for introducing other surveillance measures, such as being able to listen in on individual operators or putting cameras in the cab of each forklift. This reinforced that the goal of the new technology was to shape forklift operators’ actions in favor of warehouse efficiency; the goal was not to exact maximum control over the workers simply for control’s sake.

This example demonstrates how engineers configure users by constraining the parameters of how a technology can be used. In particular, the engineers at Supply Chain Management Company wanted to restrict how forklift operators used the warehouse and their forklifts to complete their work by arranging products in the warehouse and implementing a system that fed the operators information in a step-by-step manner. Importantly, this example also shows that configuring the user is an active and ongoing process that responds flexibly to changing needs. The engineering department had an ongoing effort to shape the actions of their workforce that was responsive to forklift operators' attempts to creatively use the technology to their own benefit. This case also serves as an example of how technologies that control users can be built into (institutionalized in) bureaucratic processes through controlling the availability and modality of information. This case also demonstrates how standards can be used to both approximate and shape user behavior. The engineers' standard of choice, the Time Measurement Unit (TMU), will be discussed in the following section.

III. Translating Technical Information for Varied Users

In order to carry out the work described in the above example, engineers have to have a certain facility with information and audiences (different groups of relevant users). Similar to the case of Priya's document matrix, the following example shows that part of understanding an audience is knowing how to present information to the users who make up the audience.

At Supply Chain Management Company, another main duty of engineers is to analyze and disseminate information about individual warehouse activity to a variety of audiences, including warehouse managers, clients, buyers, and internal stakeholders (upper management). As described above, this process involves detailed quantification of individual worker behavior that is guided by standards based on a database of time measurement units (TMUs), a productivity measure developed by Taylorist work scientists. In the mid-20th century, work scientists studied everyday work and measured typical worker movements and workplace configurations with the goal of optimizing worker productivity. As Margaret explained:

> Vinson: What is a TMU?
>
> Margaret: Time measurement unit. Also, [in our business management software], when we build all our standards for all the sides and space [inaudible] TMUs, which can be converted to seconds and minutes and hours. It's just in the [1950s] they did a lot of studies on people doing minimal things. To reach six inches and pick up a piece of paper and put it down [equals] 33 TMUs. There's this database of data that lots of industries and lots of companies use, and so we use that.

Engineers who make and use these measurements believe that being able to quantify even the smallest movements can allow engineers to incentivize work, plan hourly pay, project timelines and budgets, and track warehouse performance. These measurements also allow engineers to factor in costs associated with products that are damaged during transport or calculate the cost of a shipping delay. Because Supply Chain Management Company's engineers work in the corporate department, the bottom line is dollars and cents. Engineers send daily, weekly and monthly reports to different stakeholders advising them on current profit and future opportunities to improve efficiency. In order to communicate the proper information in the proper format to the proper stakeholder, engineers must learn how to present information in ways that are meaningful for different audiences. Margaret and Chris each compile information in a way that is meaningful and comprehensible for two different audiences: forklift operators and warehouse managers.

In the following interview excerpt, Margaret described some of the considerations involved in her information dissemination efforts. She talks about the different audiences that she shares performance data with and the unit of measurement that is most relevant to each group of users. She also mentions how this information is disseminated to different groups, as well as how some users (particularly floor-level warehouse workers) use the information to shape their work and their social relations with coworkers.

Vinson: What kind of statistics do you use, and then when does statistics become relevant?

Margaret: Sometimes I just apply them for my own benefit, track a lot of data and see what kind of trend there is. If the variance is really high, to me then it's not a good sample of data. Variance, standard deviation, and best fit, like some regression but not anything more than that.

Vinson: Gotcha. Interesting.

Margaret: Most of the metrics that we send out network wide [are] at financial levels. What was your rate of return? What was your margin? Or it's units per hour, total units, average units.

Vinson: It's very trend based?

Margaret: Mm-hmm [affirmative]. Easy to see. Everyone can understand it. Very visual, [you can] tell right when something dips.

Vinson: It seems like some of the math that you're doing and the ways that you're representing it is more designed to match what your audience can interpret rather than what you as a person can do mathematically.

Margaret: Mm-hmm [affirmative]. Yup.

In the above section, Margaret confirms that she uses different representational practices for different groups of users, and that these vary by the unit of measurement that is most relevant for different types of users. She is also aware that different groups of users have differing ability to interpret mathematical data and she adjusts her representational practices in anticipation of her audience. She continued:

Vinson: Interesting. If you [disseminate monthly company metrics], they're going out to building managers or building owner?

Margaret: Yup, and then, I don't know, the people might post them. The building owners might post them and be like, "The building down the street was at this, we were at this, and someone thirty miles away was at this."

Vinson: And so forklift operators need to be able to—

Margaret: Units per hour.

Vinson: Okay.

Margaret: Units per hour is basically all they [need to know]. Pallets per carry. You can carry two at a time versus one at a time.

Vinson: I see. It's interesting thinking about the fact that the forklift operators are also probably doing some kinds of their own math because they're constantly scanning, right?

Margaret: Constantly scanning, pallets are stacked really weird, things are interlaced. If it says you need thirty cases, that's two full layers plus seven cases. You need, oh, did I pick a layer? Interpreting whether or not I need the majority of that pallet. We call it a scoop where you instead of just taking the cases you need, you take everything and then deposit back what you don't need. We're making that trade off. They're shown there, units per hour today, yesterday, last week. It's a judge on their performance to see if they're going to hit incentive or not.

Here she describes the relevant units of measurement for floor-level warehouse workers, and also brings up some of the computational practices they use during their work.

Vinson: Do they see that on a computer or do they get a print out?

Margaret: It depends on the site. Some of them have TVs in the break room, but everyone will just print out a sheet and post it by their clock number. It actually might be by names that they can hold each other accountable. I'm not sure.

Vinson: That's a whole other layer, like a little bit of peer pressure.

Margaret: There's fights.

Vinson: Oh yeah?

Margaret: Mm-hmm [affirmative]. People telling on people. It's an hourly workforce.

Vinson: You've introduced a competitive [crosstalk 01:03:45].

Margaret: It's competitive, but it's also team based. If you just do your job as fast as you can and then screw me over, one, your observations are going to go down because you're not doing the right steps and I'm going to be super slow. No one benefits but they think they do.

Here Margaret describes how floor-level warehouse workers can use their performance information to shape their own work. In some cases, workers have access to each other's performance data and can use this to "hold each other accountable."

Like the case of Priya's document matrix, Margaret has learned that different types of information about are relevant to different groups of users. This reflects a process of having learned about the capabilities and interests of stakeholders through her everyday work as an early career engineer at Supply Chain Management Company.

The monthly company metrics Margaret mentioned above were typically compiled by Chris. Chris did the legwork of pulling together the raw data and carrying out the analysis (aided by pre-existing Excel macros and PowerPoint templates). Much of this work involved translating warehouse metrics into financial metrics because the primary audiences for the monthly metrics report were companies who sent goods to the warehouses and warehouse managers. Chris was guided closely by department management and often had to make corrections before sending the final version to the company stakeholders.

Many of these corrections were aesthetic; for example, Chris received directions from management to make sure the legends for each graph were in the same place on each slide and formatted similarly. Chris also took care to arrange each graph so that the values were arranged in ascending or descending order to represent the main message of the graph. In one case, a graph meant to display lost profits due to shipping delays might display the losses in descending order, such that bars closest to the left were from the warehouses with the most profit losses. Losses were uniformly colored red, while profits were colored green. Each bar was clearly labeled with the warehouse name. Although the primary audience for the monthly performance metrics was not floor level warehouse employees, as Margaret mentioned, warehouse owners could display these graphs in the employee break rooms to reinforce or change worker behavior.

As we discuss in more detail below, in addition to translating engineering information into more relevant metrics (like cost), using color and other aesthetic elements is an important way that engineers shape how a user interacts with a product or technology.

IV. Aesthetic Elements in Design

One element of the design process that was particularly important to early career engineers in our study was the appearance of their products. The examples discussed above indicate that engineers are attentive to aesthetics in addition to content. Investigating engineers' attention to the appearance of their products can reveal additional ways in which they anticipate user needs and shape user actions. Future work in this area will examine this theme as it relates to current scholarship in recipient design and information design.

Aesthetic elements of a product can guide users' attention, as Priya hoped to do with her colorful matrix ("It will make people *want* to read it!"). In another example, Gwen, an early career engineer from the steel mill site, was instructed to use red shading to highlight abnormal chemical values in the steel chemistry reports she produced for the daily production meeting. This would immediately direct readers' attention to the pertinent values, helping the meeting to run quickly and smoothly. Importantly, this was not an idea Gwen came up with on her own; rather, when asked why she colored the cells red, she replied, "that's how they want it." ("They," in this case, are the other members of the quality team who handed this task off to her, in addition to the woman who runs the daily production meeting.) This use of color to guide attention was also present in the monthly metrics Chris compiled for the supply chain management company.

However, the importance of appearance for engineers in our study transcended the use of color. Engineering itself contains aesthetic standards for presentation that are noticeable primarily in engineering drawings (formal drawings, not including sketches). Here, it is an aspect of engineering aesthetics to 'leave no trace,' making engineering drawings usable by other engineers, i.e. free of idiosyncrasies. Engineers in our study described this as very important. One way they accomplished this was by inscribing all necessary information into the drawing using widely recognized symbols and drawing conventions; if the engineer were to leave behind personal touches, it would be possible that another user would not understand what the intent was, thereby restricting the general usability of the product.

A second way that engineers attempt to make their products widely usable is to use conventional symbols in drawings and to clearly note all measurements and dimensions, leaving no interpretive flexibility or confusion about what the drawing represents. Engineers find that this is particularly important for assembly drawings and electrical diagrams and engineers may go through several rounds of corrections to make sure that multiple page drawings of a single system are complete, correct and consistent. We observed this carried out in conjunction with a more experienced engineer who provided written edits and used a highlighter to mark areas that should be changed. We observed multiple rounds of corrections of drawings carried about by Sasha (steel mill) and Priya (elevator company).

There is also a moral element to having neat, conventional and accessible drawings that points to the moral dimensions of aesthetics in engineering. While the responses of more senior engineers were mixed as to the importance of color and visual appeal in engineering design, they were nevertheless attentive to the aesthetic elements of engineering design. An example of this is Gabriel, who supported Priya's desire to format the document matrix, but who did not want that to slow down her ability to make content-based changes during their team meeting. Other senior engineers, such as Tom, who mentored early career engineer Ryan at the steel mill, were attuned to the moral elements of aesthetics and used them as a way of talking about other professional aspects of engineering like work ethic and reputation for doing good work.

Discussion & Conclusion

Research in Science and Technology Studies attends to ways in which designers 'configure' the user by constraining the possible future actions of the user through the design of products and processes (Woolgar 1990). However, configuring the user implies knowledge of the user. In this paper, we used examples from engineering workplaces to show how early career engineers learn about the users of their products and how they participate in designing products and systems that shape the actions of those users. Our findings reveal that designing for users is simultaneously a process of anticipating user needs and actions and using the product itself to guide the user's use of it.

The first section of the paper attended to situations where the end user was unclear to the early career engineer or when the end user could be a wide range of people. In these situations, early career engineers learned to be cognizant of the user of their product—it was not simply enough to make a product that satisfied engineering standards or accurately reflected company information. This section drew attention to the relationships early career engineers have with more experienced engineers in the workplace and how, by working in mixed-experience teams, early career engineers learn who the users of their products are and how to accommodate them during product design.

The second section of the paper focused on controlling known users. Using examples from a supply chain management company, we showed how early career engineers use industry standards and new technologies to regulate the work of warehouse employees.

In the third section we showed how engineers translated performance metrics into forms that were relevant to different stakeholders in the organization, including floor level warehouse employees. These metrics are framed in ways that are relevant for the different stakeholders, including financial framings, time-based framings, or month-to-month trends. By explaining the rationale behind these systems of control and information use, we were able to show the overt priority in the engineering department of controlling warehouse floor workers by shaping the parameters of how workers can use the technology and machinery of their everyday work.

Our analysis also attended to the importance of aesthetics in information design and presentation. We found that engineers were focused on aesthetic elements such as color, spacing, and orderliness of documents and products, and that the presentation of the product could take on a moral character that reflected on the engineer him/herself.

Our analysis has certain implications for engineering education. First, by observing early career engineers in the workplace, we are able to show the typical range of activities and tasks carried out by early career engineers. We are also able to observe workplace learning in action. Increasing scholarly understanding of the everyday work of a newly graduated engineer can help engineering educators identify areas of the curriculum that can be modified to develop at the undergraduate level the skills early career engineers need to have.

Second, by describing the context in which early career engineers learn, we are able to show that engineering is not merely a technical enterprise, but a socio-technical enterprise (Stevens, Johri & O'Connor 2013). There are complex networks of stakeholders and users that early career engineers must learn to work with; while some are clients, others may be coworkers, managers, colleagues from another department, etc. Unlike engineering undergraduates, who may primarily only think of engineering as a form of technical work, professional engineering work is simultaneously the work of organizing people, institutions and things (Suchman 2000, Adams et al. 2011).

Finally, one aspect that distinguishes workplace learning from engineering education activities that simulate real-life engineering is that early career engineers work in hierarchical teams where members have varying levels of expertise and experience. This stands in contrast to peer teams, where each student has comparable expertise. Working with a team where the members have differing levels of experience with the user of the product may help early career engineers learn how to represent users better during design than working on peer-only teams. Understanding the importance of early career engineers working on teams with more experienced others can help to show how the technical aspects of engineering are inseparable from the social work of coordination, learning, and labor.

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