Making Meaning from the Digitalization of Blue-Collar Work

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With rapid advances in computing, we are beginning to see the expansion of technology into domains far afield from traditional office settings historically at the center of CSCW research. Manufacturing is one industry undergoing a new phase of digital transformation. Shop-floor workers are being equipped with tools to deliver efficiency and support data-driven decision making. To understand how these kinds of technologies are affecting the nature of work, we conducted a 15-month qualitative study of the digitalization of the shipping and receiving department at a small manufacturer located in the Southeastern United States. Our findings provide an in-depth understanding of how the norms and values of factory floor workers shape their perception and adoption of computing services designed to augment their work. We highlight how emerging technologies are creating a new class of hybrid workers and point to the social and human elements that need to be considered to preserve meaningful work for blue-collar professionals.

CCS Concepts: • **Human-centered computing** ~Human computer interaction (HCI) ~Empirical studies in HCI

Additional Key Words and Phrases: Manufacturing, Organizational studies, Future of work, Mobile devices, Augmented Reality

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1 INTRODUCTION

It is nearing the end of a nine-hour shift as the heat is slowly making its way into the building on a hot summer day. Just inside the loading dock, protected from the sun, a group of six people encircle a sixteen-foot pallet loaded six feet high – saran-wrapped, strapped, and secured for shipment. The group shifts around the pallet as fingers are raised and discussion commences. Part numbers are called out from the paper sales-order and located one by one on the pallet. Debate ensues about the positioning of a hard countertop surface that could be at risk of getting damaged during the long journey ahead. Tensions rise as the final judgment is made by the most senior leader. The order must be repacked. The shipping employees hastily walk away angry and annoyed. In angst, one of the employees loudly proclaims, “If they wanted to pack, they can come do our jobs” followed by “They don’t know what they’re talking about.” The shipping employees took the decision personally

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because their professional identities were deeply connected the tangible outcomes of their work and their role in protecting the reputation of the company and the labor of their peers. This extra level of scrutiny was required because customers were taking advantage of the lack of digital documentation and quality records by claiming they did not receive a complete order and requesting free replacement parts. Communication for the shipping employees still relied on paper documentation and word of mouth which increased opportunity for error and decreased traceability. Common interests in resolving customer complaints united leadership and shipping employees in their desire to implement new digital tools to modernize the process of loading and packing orders.

It was in this effort of digitalization that we began a 15-month study to implement and deploy a pilot system augmenting the work of the shipping employees to reduce error, improve documentation, and address quality control. The process intervention chosen by the company was an off-the-shelf software and hardware solution that digitized work instructions and inspection procedures for employees in the shipping and packing department. These technology upgrades were viewed by leadership as a mechanism to establish transparency and enhance data collection necessary to achieve a 'connected' factory. We were particularly interested in understanding how these new kinds of data-driven tools would be adopted across the organization and change workplace practices for the shipping employees. Our study traces the effects of digitalization on the blue-collar workforce and provides a detailed depiction of what it means to be a modern factory floor worker.

Recent calls in CSCW and HCI have urged researchers to return to workplaces to understand the social and human dimensions of frontline work that are being rapidly transformed by computing [16,23,36]. Given the legacy of automation in manufacturing, industrial contexts provide an opportunity to understand worker perspectives as new categories of technology are being embedded on the shop floor in novel ways. Paradigms surrounding The Industrial Internet of Things (IIoT) and Industry 4.0 encourage the adoption of data-centric technologies to support decision making and to deliver operational efficiencies across the entire organization [12,36]. From back-office, process-driven systems, to specialized hardware for monitoring and sensing equipment, to devices and services that augment human labor, the factory of the future is a complex cyber-physical system [36,42,66]. Extending far beyond the conventional office historically at the center of HCI research, we need to carefully consider how people and places are being automated to design technologies that support organizational goals and preserve the dignity of work.

In the face of the COVID-19 pandemic – amid reduced workforce, increased unpredictability, and disruptions in global supply chains – we have seen increased commitments to automation across all scales of manufacturing [18,42,70]. While the pandemic added additional urgency to adopt new technologies, there was already pressure to improve manufacturing processes to meet market demand for faster turnaround times and product customization [31,53]. However, leveraging the capabilities of new digital technologies and the resultant data remains a struggle for the majority of manufacturers in the United States [67]. For small and midsize companies, digitalization is particularly challenging because work is dynamic and limited resources result in piecemeal upgrades [67]. A consequence for all but the most well-resourced manufacturers, who can develop custom systems through participatory processes, is that new technologies are often embedded with managerial techniques that can limit progress and productivity [28,68]. To reap the potential benefits of digitalization requires reframing how automation is designed, otherwise we risk perpetuating 'capitalist modes of production' that disempower workers [13,39].

Despite the clear gap between how worker augmentation and automation systems are designed and where and by whom they are used, limited research has occurred at the intersection of automation design, user experience, and workplace settings [57]. Several persistent challenges remain, including: a lack of access to workplace settings, and organizational demands for performance that prevent long-term studies in context, and minimize employee engagement in the design process. The need to create engaging worker experiences that are situated in context is more urgent now than ever before as digitalization outfits workers with new forms of automation. Our work seeks to shrink this gap by providing a detailed depiction of worker experiences as automation is being designed and implemented on the shop floor at a small manufacturer.

In this paper, we highlight the worker perspective and begin to unpack the values tied to blue-collar work that need to be preserved during the technology design process. We trace the effect of digitalization on workplace practices as shipping employees were equipped with wearable and mobile devices that enabled access to electronic work instructions and created digital records for product quality. Together, company leadership and the shipping employees sought to protect their work and strengthen customer relationships through digitalization. However, inserting technology into a predominately manual process upset power dynamics and job satisfaction by going against traditional notions of efficiency and empowerment. The outcomes of our analysis point to the need for design to address different value systems across blue- and white-collar work. We need to be able to clearly articulate these differences to create technologies that positively impact the future of work – not just developing tools that are useful but creating jobs that are meaningful in the face of automation and the enabling data economies.

2 IMPACTS OF DIGITALIZATION

To begin to understand the potential effects of digitalization on blue-collar workers, we need to examine the longstanding relationship between automation and labor in manufacturing. Previous waves of technological transformation sought to limit the impact of human error on manufacturing processes. Now, new technologies are seeking to optimize human labor and cognition as a part of the digital workplace. We then turn to organizational studies to explore the influence technology can have on individual workers. Examining the use of new systems and devices in white-collar domains illustrates how technologies have shaped our personal and professional identities. Decades of scholarship has helped us understand the experience of what it means to become a connected knowledge worker, but less is understood about what this amounts to in a setting other than the white-collar workplace. Considering the role of automation in manufacturing alongside the transformation of white-collar work, we can begin to draw inferences surrounding the challenges and potential consequences of shop floor digitalization.

2.1 Transforming Manual Work

Researchers in CSCW and HCI have long traced the waves of technological transformation from mechanization to mass production and digitalization occurring in industrial environments. In manufacturing, automation has been a source of economic progress that has transformed the industry through productivity gains and increased safety, with the premise of distancing workers from dirty and dangerous tasks [7]. However, there has always been a contentious relationship between labor and automation revealing issues of power and control, expertise, and job over-simplification and -specialization [11,49,76]. The history of automation design in manufacturing is fraught with managerial techniques (i.e. Taylorism, Fordism) that wrest control away from end users to minimize human error and optimize output [19,35]. Too frequently, the new technologies introduced into manufacturing settings, while aiming to be useful, propagate issues of social injustice and perpetuate cycles of employee disempowerment [10,37,38]; the humane experience of work is the casualty in the quest for increased efficiency, productivity, and volume. To advance alternative approaches to technology design, we take up the call to pay attention to the bodies and sites where automation occurs so that we can unveil other interpretations of progress that prioritize worker contribution, expertise, and dignity [37].

While we have witnessed the "transition from the craftsman as a skilled manipulator of tools to the industrial worker as an operator of a special purpose machine" [22], we are now entering an entirely new phase of automation: worker augmentation. Where earlier instances of automation sought to remove and distance human labor from the shop floor [49], in the connected workplace, the blue-collar workforce is being further embedded into the instrumented environment, equipped with wearables, sensors, and specialized hardware [56]. What makes these forms of automation different is new levels of wearable technology embodiment extending the body, cognition, and self [48]. We are already beginning to see what this looks like in large manufacturing organizations. Augmented reality is being worn by blue-collar workers to provide instruction and guidance for assembly and maintenance tasks [2,14,54,74]. Virtual reality devices are used to train workers by replicating the job in real-world scale [9,25,60]. Collaborative robots are becoming new colleagues on the shop floor, performing physical tasks and interacting with employees [43,62]. These tools are attempting to create organizational efficiencies by leveraging of human capabilities [17]. Yet, limited research has investigated if these kinds of assistive technologies are supportive or even desired by frontline workers.

The movement towards adopting data-driven technologies as a part of Industry 4.0 is coupled with creating Operator 4.0 [56]. Visions of factories of the future rely on workers and technology being seamlessly integrated creating more desirable jobs and 'smarter' employees by giving them new skills. It is easy to assume that workers want upward social mobility granted through tech skills and access, but that does not align with all contexts of work. Surveying the replacement of tasks with traditional robotics, researchers have found cases resulting in new skill development for pilots and warehouse workers, but the reduction of skill and increased job dissatisfaction for transportation drivers and doctors [63]. The meaning of work is intertwined with professional practice and individual values associated with particular skill sets [63]. As previously recognized, automation is directly affected by professional identity, making it imperative to contextualize technology design so that it reflects organizational values and norms [58,59].

2.2 Transforming Manual Workers

To contend with the complexities of workplace settings, we draw on organizational studies to reveal the effects of technology on individual practices and organizational structures [8,50]. We can look to major inflection points in HCI and CSCW where work practices were transformed: the introduction of personal computers into office environments [28,50,77], the effects of groupware applications like email [29,33,51], and more recently, the adoption of smartphones and personal devices [45]. The use of these technologies led to the creation of a whole new kind of knowledge worker: the smart phone hybrid worker [44]. White-collar professionals have become hybrid agents intertwined with cell phones, laptops, and the Internet unable to separate ourselves or our identities from the tools that we use [44,46,47]. While this level of connectedness has created opportunities for information sharing and access, not all the outcomes have been good.

Connected devices and tools hold the ultimate promise of control, autonomy, and separation but they simultaneously undermine each of those elements [26,37,47]. These tools do not actually grant individuals more control over their actions or schedules but rather control individuals through regimented rituals [26,44]. For mobile devices, being available and online are propagated by the internal properties of the tool itself; We have become slaves to the dings, vibrations, and alerts [26,46]. We cannot actually unplug without giving notice because it is viewed as a choice and interpreted as a "lack of respect love dedication" [44]. By reflecting on how technology has affected white-collar professionals in traditional office environments, we can begin to imagine the kinds of changes we can expect to see as these devices make inroads into blue-collar domains.

We can conceive that when hourly workers are required to use these same kinds of productivity tools at work, the guise of control and independence are further lost. Blue collar workers are often in a subordinate position of power where they are not able to say no or set their own schedule availability. Equipping workers with new tech also comes with the recognition that they fit a standard user profile with enough financial means for a phone plan, access to Internet, knowledge, and capability to use these kinds of tools. While many fit the ideal user profile (and want to), we neglect to consider those who do not, and we disregard the ways that devices shape us as users arresting our attention and distancing ourselves from others. We need to carefully consider the professional boundaries that these tools remake while we can still affect technology design for blue collar professionals.

Part of the difficulty in developing technologies that support individual work practices is determining the values and priorities unique to each setting and user group. In CSCW, there is a long line of work that points to the difficulty of designing technology that can provide the flexibility workers require [e.g.59,61,67]. Key challenges include determining routine tasks, allowing for deviations in work, and navigating permissions and access for different domain spaces, all while maintaining worker autonomy to meet changing goals and respond to the environment as the day unfolds[1,27,30]. This has only become more difficult with growing organizational and technological complexity [30]. As a result, we can expect to see workarounds that uphold an individual's understanding of how work gets accomplished [52].

While far fewer in number, there are studies that show successful adoption of technologies that support employee practices. Grinter highlights four elements that enabled successful use of workflow systems for software development: "(1) the developers understood and accepted the model of work, (2) it provided understandable and useful representations, (3) the "right" work was automated and (4) the corporation was supportive" [27]. While there is clearly a desire to adopt new workflow technologies in manufacturing to become more data-driven, we do not yet understand how Industry 4.0 systems and devices effect different modes of work outside of white-collar domains. White-collar work revolves around different kinds of data and knowledge production, making the role of, and the case for computational tools more obvious. In contrast, blue-collar work is about producing physical goods and is often based on embodied expertise that is not as directly amenable to computational support. By exploring the design and use of new technologies being adopted in blue collar domains we can begin to understand how Industry 4.0 technologies substantiate the requirements laid out by Grinter in other diverse contexts of work.

3 CONTEXT AND METHODS

We spent 15 months studying the implementation and use of a new process intervention in a small manufacturer located in the Southeastern United States. The manufacturer in our study was a well-established employer, operating for more than 20 years in a small rural community, but was undergoing a transformation both culturally and technologically. The company produced cabinets and components including counter tops, metal doors, bathroom partitions, and lighting tracks for commercial grade settings. Established fast food chains accounted for a majority of company sales and revenue, but these businesses were hard hit by the recession in 2009. The manufacturer exchanged ownership in 2015 which prevented the business from closing its doors. New leadership garnered respect and admiration from employees because they kept the existing workforce (50 people) and implemented positive changes including facility upgrades and investments in new equipment and project management systems. These improvements created a company culture that embraced automation as a vital part of remaining relevant and competitive.

Our study of the digitalization of the shipping department was motivated by the manufacturer's commitment to progress through automation. Company leaders and the shipping employees had the shared goal of wanting to modernize the shipping process by creating the ability to track and trace order content. Having detailed documentation gave company leaders the ability to refute customer requests for free replacement parts based on claims of incomplete orders. The shipping employees took these claims personally and wanted documentation to show proof of a job well done. From leadership's perspective, becoming more data driven supported worker wants and needs as well as increasing profitability. A mutual goal was also eliminating clunky and outdated processes and systems. The shipping department was one of the last remaining areas on the shop floor to undergo a technology transformation.

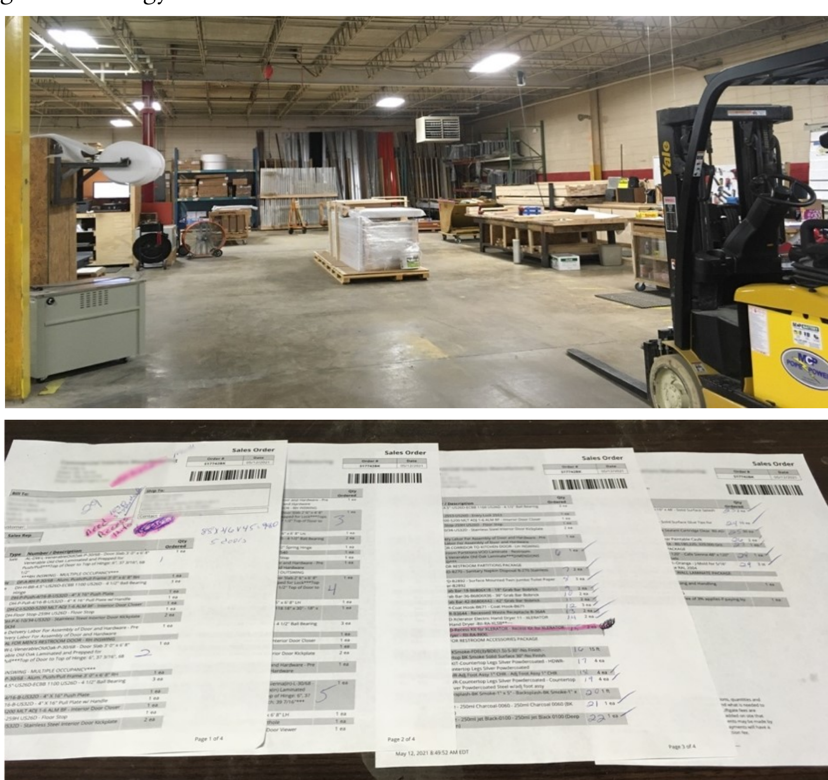

Fig. 1. Top- Shipping Department Workspace; Bottom- Sales Order Example.

We conducted observations as well as pre- and post-intervention interviews with three full-time shipping employees, and the management team including the shipping supervisor, production manager, and chief operations officer. Our initial field work informed tech selection and provided a foundation for understanding the changing nature of work. We identified an existing off-the-shelf solution that fit within company budget and resource constraints to create quality documentation in the shipping department as detailed below. The solution provider offered the manufacturer a discounted rate for a yearlong software license to trial the system. In exchange for continued access to the organization, our research team supported implementation by customizing the solution and training the shipping employees. We clearly communicated our role to all study participants including the shipping employees and management during the consent process and kick-off meetings in accordance with approved institute review board guidelines.

3.1 Shipping Processes and Procedures Pre-Intervention

The shipping department in our study was responsible for packing orders, building custom crates, and performing quality assurance. The work was carried out by three full-time shipping employees and was overseen by a shipping supervisor, production manager, and chief operations officer. Prior to our intervention, the shipping and packing process was initiated by the supervisor who gave a list of order numbers scrawled on college ruled paper to the shipping employees every Monday morning. The shipping employees then printed off corresponding sales orders using the desktop terminal located in the shipping department (See Fig. 1). Packing orders consisted of product handling and component picking. Product handling meant bringing finished products from production to the shipping area manually or using a forklift. Component picking involved gathering hardware and accessories like bolts, caulk, and sealant from inventory. Once all components were collected, a custom pallet (up to 16ft long) was then built. The order was then packed and a quality check sheet was completed requiring shipping employees to double check each part number on the crate. After performing quality assurance, the order was enclosed and secured for shipping using additional packing materials. Final documentation tasks included updating item counts in the inventory management system and logging the time when the order was packed on Google Sheets. To manage complexity, the most tenured shipping employee took ownership of the computer tasks – printing off sales orders, updating the inventory management system and logging time stamps. All paper documentation (sales order, quality check sheet) was then given to the supervisor signaling that the order had been completed and placed at the loading dock. These steps detail the ideal process flow for one order, illustrated in Fig. 2, but the daily roles and responsibilities of the shipping department were more expansive.

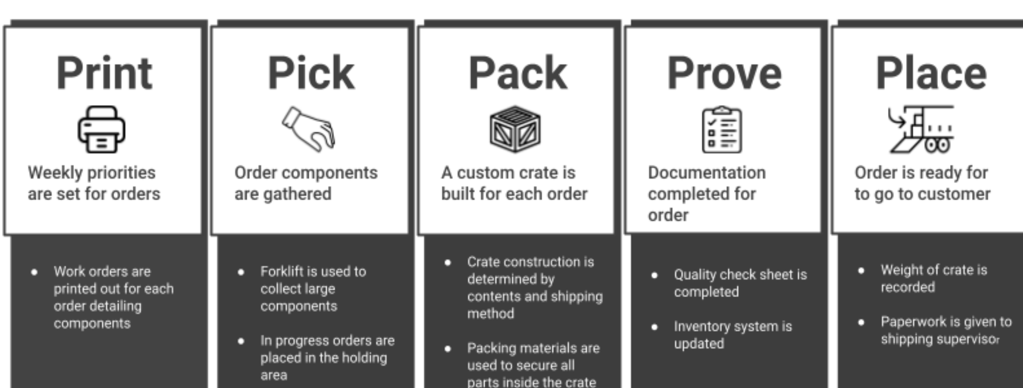

Fig. 2. Existing Shipping Process.

Given the dynamic nature of manufacturing, shipping employees had to respond to production readiness resulting in fluctuations in work and order priorities. The shipping department not only carried the responsibility of performing the final quality check but also making up for lost time due to supply chain issues, production errors, or client demands. For example, rush orders took priority over any outstanding tasks and production delays could recalibrate shipping priorities for an entire week or more. To compensate for uneven work volumes, shipping employees performed miscellaneous tasks like emptying dumpsters, fixing equipment, and loading and unloading raw materials. Additionally, they acted as primary forklift drivers across the facility. The variety of job tasks was unique to the shipping group and gave employees the ability to traverse the shop floor and communicate with their peers.

3.2 Process Intervention

Working in tandem with the manufacturer, our research team identified an off-the-shelf solution to create records of product quality and order completeness in the shipping department. All participants in our study were involved in technology demonstration sessions held at the manufacturer to give input and provide feedback on software and hardware. A priority for selection was leveraging readily available devices and software packages to put into place a solution that could be easily maintained by the manufacturer after the completion of our study. As a small company, the manufacturer did not have dedicated information technology staff. Our research team fulfilled this role by assisting with software selection, integration, and training in exchange for access to the organization. Our interest was in understanding the changing nature of work as employees underwent a technology transformation. Full scale implementation and use of the process intervention occurred from January to June 2021.

3.2.1 Software and Hardware Selection. The software solution used in our study was marketed as a digital workflow tool for Industry 4.0 manufacturers. The authoring platform allowed administrators to create custom procedures to digitize work instructions and inspection processes. Administrators also had access to real-time tracking via a web-based data dashboard that logged location, time, and user information. The entire software solution was device agnostic and compatible on both iOS and Android. More importantly, it could be integrated with the new project management system used by the manufacturer. This built-in functionality was critical because the size of the company meant that there was no internal IT department, making creating and maintaining a custom solution cost prohibitive.

In conjunction with company leadership and the shipping employees, we initially selected Google Glass Enterprise Edition devices but transitioned to mobile devices for the duration of our study to match the familiarity of workers. Glass was attractive because the devices were hands free, and they also served as safety shields and provided the ability to scale to other areas across the shop floor. However, for reasons that will become clear below, the company moved away from Glass after 6 weeks and used the mobile application for the remaining 5 months of the study. Smartphones were quickly adopted – confirmed by increased usage statistics captured by the software.

Fig. 3. Wireframes of Mobile Interface.

3.2.2 Device Description. The mobile application was downloaded on personal devices for all employees in the shipping department. Each employee completed a one-time login procedure creating a unique user ID. On the home page, operators could view tasks in work queues: to do, in process, and completed (See Figure 3). The 'To-Do' queue was a shared queue visible by all shipping employees. 'In Process' and 'Completed' were unique to each individual user profile. We granted the shipping employees administrator permissions so that they could see work queues. Interactions within the application included swiping between screens and tapping to snap pictures of order items.

3.2.3 New Process Flow. To initiate the new process, shipping employees would open the software application on their mobile phones to scan the barcode at the top of a sales order, shown in Fig. 1 above. A sales order would be displayed showing the total number of pictures required for the order. Workers would then proceed to take a picture of each component line item in the order when prompted within the application. Capturing item pictures eliminated the need for the quality check sheet. A final picture of the entire crated order was also required to complete the process. Then an individual PDF report was automatically generated for each order and sent to supervision via email containing all the associated pictures. Leadership was also enrolled in text message notifications that provided instant updates when an order was started, stopped, or completed. All final PDF reports were automatically uploaded to the project management system at the end of each day and attached to the corresponding sales order number. The report and item pictures were then accessible to everyone who had access to the project management system. The new process flow is reflected in Fig. 4.

3.3 Data Collection and Analysis

We conducted ethnographic observations and interviews from March 2020 to June 2021. During this time, our research team had open access to the manufacturing facility. Approximately 280 hours of field observations were completed. All site visits were conducted in half or full day segments and entailed shadowing the shipping employees as they went about their daily tasks. Informal conversations occurred with workers throughout our site visits. To capture quotes and context in the moment, handwritten logs and voice-to-text memos were accumulated creating a set of ethnographic field notes [21]. We also used hand drawn process flow diagrams to facilitate

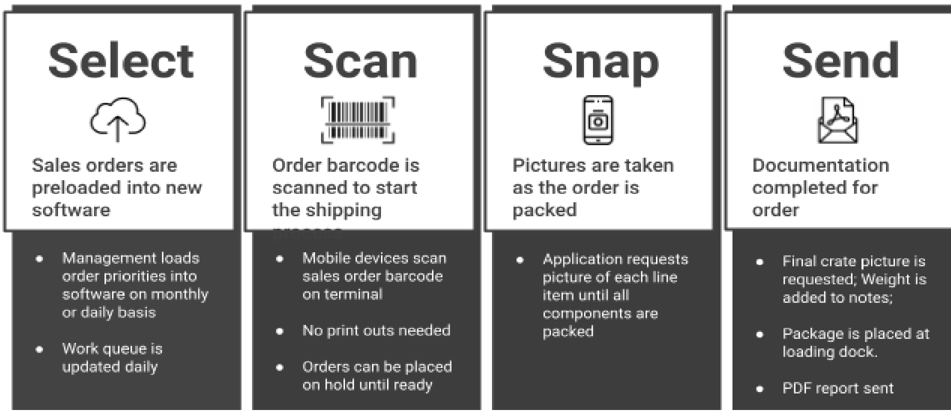

Fig. 4. New Shipping Process.

conversation. Allowing employees to point and scribble on top of our process diagrams gave us insight into daily operations and work tasks in the shipping department.

Supplementing our observations, we conducted pre- and post-intervention interviews with all three of the shipping employees and management, including the shipping supervisor, production manager, and chief operations officer. The focus of the pre-interview was to document experience levels and expectations of technology. The post-interview served as an opportunity to reflect on the project and share lessons learned as well as future outlooks. Taken together, these forms of data collection helped us develop a robust understanding of the intentions and attitudes surrounding technology adoption and use in the workplace. Being in the field was essential to gathering a more complete picture of blue collar work and the kinds of invisible labor not captured in formal interviews alone [20]. Assisting with roll out and training also provided an opportunity to identify specific design opportunities, but the focus of this paper is on the role of technology in the context of work for the shipping employees.

We analyzed all our data – interview transcripts, field notes – inductively using grounded theory practices until a set of themes began to emerge [8]. Drawing on Charmaz's version of grounded theory allowed for more flexibility to embrace the diversity of participant experience and respond to ongoing change [15]. Following a process of open coding and constant comparison between our interview transcripts and ethnographic field notes, we created memos for an initial set of themes including *power and authority*, *autonomy and identity*, *accountability*, and *predictability.* Refining our overarching themes continued to reveal disjunctions between employees and leadership who responded differently to the creation of new kinds of data. These perspectives portrayed differing expectations of technology and assumptions about the kinds of work and skills people wanted to perform. In our findings below we focus on the impact and consequences of our process intervention on workers to highlight the transformation of blue-collar work as a result of new data-driven technologies.

Following in the tradition of workplace ethnographies and feminist approaches to design [6,24], we foreground the experiences and practices of workers as experts in our research. To preserve the active voice of workers and study participants, names have been anonymized using pseudonyms. Key to our methods is acknowledging our positionality. As researchers intervening in practice, we became actors within the system, bringing with us our biases which also created opportunities for common understanding and shared experience. The first author was one of the only females present on the shop floor. The feminist ethos of care and empathy acted as instructive tools that helped open lines of communication between the first author and the employees. Additionally, the first author's background and professional experience working in manufacturing made it easier to assimilate into the environment and build trust. While initial reactions to observations and interviews were met with skepticism, the duration of the study enabled a deeper level of knowing, forming strong bonds with shipping employees and company leadership. Regardless, as researchers, we were coming from a place of privilege and supporting implementation could have affected the sentiments and feedback received by workers. We accept both the affordances and consequences of our methodology as a means to provide a detailed depiction of worker experiences.

4 FINDINGS

Our findings focus on the people and tasks in the shipping department, drawing attention to the norms and values of blue-collar workers as their routines were transformed in pursuit of data-driven decision making. Observations of existing workplace practices and pre-intervention interviews revealed the importance of diversity, predictability, and consistency to the shipping employees. These values informed the *form and function* of the process intervention and provide traction for examining workers' actions and reactions as the solution was rolled out. Tracing the implementation and use of the intervention draws attention to the importance of the *optics of aid* and the *redistribution of work and power*. Characterizing the impact that new technologies have on blue collar workers and organizations points to the complexity of designing workplace solutions. Opportunities exist to reimagine how technologies deliver meaning and value to different classes of workers situated within the context of use.

4.1 Determining Form and Function

The shipping employees represented three vastly different generations, but they shared a common set of experiences and values that shaped their professional identity and informed their technological frame [52]. Peter was the youngest member of the team, at just under 25 years old, having recently relocated to the area for family and had been with the company for approximately one year. Paul who was between the ages of 45-50 years old had worked for the manufacturer on and off throughout his career with over 15 years of experience in roofing and construction. Tom was the eldest in years of service and age at over 65 years old with more than 30 years of experience in construction and 15 years with the current company. They all were entrepreneurial in spirit and had experience running their own businesses and side hustles. Each possessed a job history that involved working outdoors in construction related roles. What attracted them to manufacturing was protection from the weather and a consistent stable income. What kept them coming back was the people and the work.

Each employee shared that they had "found their fit" in the shipping department because of the diversity of tasks and ability to traverse the shop floor. According to Peter "*I'm not stuck in one area, you know, I'm all over the place, you know, I'm not doing like the same thing over and over again*". It was commonly expressed that the worst job on the floor was being a machine operator – stuck in one place pushing a button all day (field notes). The ability to "*roam around and check and see what I got coming to me*" gave Tom a significant level of autonomy. He continued to share that "*I'm my own boss, and I think, and I'm not trying to brag or nothing, I think I'm pretty good at my job, And I love my job.*" Paul expressed similar sentiments: "*I like putting stuff together, figuring out, you know, I like doing the damn pallets and stuff like that.*" All the shipping employees especially appreciated that their work made a big impact for the company and "*people actually notice it*" when it goes out the door. What made the shipping employees love their jobs was the autonomy and flexibility, as well as seeing the tangible outcomes of their work. Tasks that ran counter to these values were viewed as tedious and nonproductive which created a tumultuous relationship with technology.

Prior attempts to create documentation resulted in the installation of overhead video cameras adding new tasks while also limiting the workspace for shipping employees. The extra labor involved in making the ad-hoc system work was a constant source of irritation. Workers had to enter the start and stop time in Google Sheets for every order they packed. These time logs were used by management to review footage in the event of a customer complaint. Based on our observations, employees would often forget to enter times and were left guestimating hours later. The biggest frustration shared by Peter was "*just the hassle of having to go over to the computer, you know?*" The shipping employees disliked computer tasks because they disrupted the flow of work and slowed them down. Additionally, the camera capture zone limited the physical workspace; Orders could only be packed within the area visible to the camera. This neglected to address the fact that work happened across the shop floor. The shipping employees expected technology to deliver more flexibility and match their movements, akin to the personal wearable and mobile devices they already possessed.

According to the shipping employees, the most difficult part of working in shipping was dealing with the lack of predictability and inconsistent work volumes. They would go from having no work to being told to hurry up by supervision because the shipping truck was waiting at the loading dock. Paul expressed his dislike for unpredictability by saying "*Sometimes we'll go from empty to full quick, and then our, um, or also get slammed at the end of the day even...and then, you know, we have to stay a little late to get it all out.*" Limited access to information meant that the shipping employees could only respond to what they had been told to do; they could never anticipate or plan ahead, they were always reacting. Part of the promise of new technology is delivering information to support decision making for leaders but there also exists an opportunity to support blue-collar professionals in the same way.

4.2 Optics of Aid

We put documentation into the hands of the shipping employee allowing them to freely move about the shop floor while creating quality records by taking pictures of order items with Google Glass. The form factor of Glass aligned with expectations of mobility and blended into the environment as certified safety lenses. Additionally, Glass maintained professional boundaries because the headsets were owned by the manufacturer and to be used only for work. The shipping employees claimed to be excited about using the wearable devices during hardware evaluation sessions, but adoption never fully occurred. The novelty of the devices did not outweigh the perception of aid that diminished how workers saw themselves.

As a wearable device, Glass was an obvious tool that made workers standout on the shop floor and suggested that they could not do their job without help. Workers would only put-on Glass as soon as they saw a research team member enter the facility. Although required, safety glasses and hearing protection were not popular for shipping employees to wear even though the environment was exposed to debris and high decibel equipment. Initially our research team asked for ear plugs which were found in an unopened box in a storage cabinet. We transitioned to bringing our own protective equipment for the duration of the study. Being hard of hearing and having scars from work was a badge of honor. One of the shipping employees previously had a heart attack on the job and was constantly showing the research team his scar as a reminder of his loyalty and commitment. Even while the study was occurring, Tom cut off a major section of his thumb received 15 stiches and, as a point of pride, came back to work the next day. Glass undermined the identity of the shipping employee’s as tough, self-sufficient individuals.

To workers having technology blend into the background meant that the device did not conflict with their perception of being 'able' or not. This was exacerbated by on-the-job training. Workers would get frustrated with having to ask for help which meant screen sharing their view in Glass on the computer terminal in the shipping department. This attracted attention of their peers who would tease the shipping employees making statements like “*Glass girl has to tell you what to do.*” Glass upset notions of being self-taught and capable. It was seen as weakness and a sign of poor performance. How assistive tech is positioned within a given community plays a critical role in adoption and use. If everyone had been required to use Glass on the shopfloor the outcome could have been very different.

In contrast, the phone-based form factor was supported by familiarity, but also perceptions that cell phones served individuals and supported their needs [47]. The shipping employees did not associate mobile devices with the downsides of using the traditional computer terminal - stationary clunky and overly complicated. Prior to our study, cell phones were not technically allowed on the shop floor, but smart watches and blue tooth headsets had become pervasive. Listening to music and getting alerts, even if unable to respond, kept employees engaged and connected to the outside world. As Peter shared “*We kind of like already have my phone on me anyways, maybe in my pocket, you know, so on it all day anyways.*” Adopting the phone-based platform meant devices could be visible and in open use in the shipping department.

Signaling a shift in hierarchies and labor tasks, Paul shared “telling somebody, I get to use my phone at work, I'm using my phone at work with them [supervision], to do work. Now that is wild.” Paul continued by saying that he envisioned himself being able to check-in from home on his mobile device and see what was on the docket for the next day: "A lot easier for a fella, because I could come in, I could do it right before even coming in." The shipping employees saw themselves as gaining status on par with supervision by being able to use their mobile devices at work. However, expanding access can also lead to consequences like immediacy and the always-on mentality we have experienced in white collar professions [26,44].

4.3 Redistribution of Work and Power

The process intervention changed how information flowed to the shipping employees and how work was delegated within the team effecting hierarchies of power. Previously, managing the paperwork and performing computer tasks in the shipping department was undesirable because they added more stress to the job. The complexity of these tasks led the senior shipping employee to take ownership reinforcing his seniority. In contrast, the mobile application eliminated the paperwork and replaced the stationary computer terminal with more accessible and discrete devices giving all the shipping employees access to sales order data to predict and plan ahead.

The distribution of information meant that each shipping employee could see a sales order through the entire shipping and packing lifecycle requiring a new kind of coordination work. Rather than work priorities being flowed from the supervisor on a weekly basis, shipping employees had access to sales orders in the ‘To Do’ queue months in advance. Paul described the process as less stressful by “*Being able to go in there and just open it [mobile application] up and be able to scan and stuff and get it instead of having to wait, like the process of doing like paperwork kind of stuff.*” The first person to scan the order claimed responsibility for the entire lifecycle including orchestrating how the crate was loaded to capture the required pictures. Communication between the shipping employees became paramount as the leadership role changed based on who was capturing pictures for the order.

Offloading task delegation to the software platform aligned with management expectations but changed the dynamic of power within the shipping group. The technology assumed a supervisory role telling workers what to do and orchestrating the process flow. The role of the software as viewed by Tom was that "*It tells me what I'm doing*" and "*It gives them [leadership] the idea that I'm doing the job.*" Workers were being instructed what to do by the software, as Paul explained, "*we can't crate it up until the pictures are taken, you know? So kind of like, you're not given a choice.*" The cadence of the software reorganized the flow of work and provided more information, but the trade-off was loss of agency. As described by Peter, "*We'll get everything together and have it right there because it made us.*" Endowing technology with the ability to provide direction created a new kind of hierarchy where workers were beholden to technology downplaying the tacit knowledge and experience of employees.

In response to shifting hierarchies, Tom, the senior shipping employee, created a shadow system that endowed him with the autonomy and control he sought to maintain. Following several weeks of on-the-job training with the mobile devices, Tom ran up to the research team and proudly exclaimed "*I figured it out by myself*" pointing to the application on his phone. He proceeded to show us how he had made the application work for him: "*I could look at my [paper] work order and see which one we had on the crate, you know, and I would go to that number [on my phone] and get a picture of that one.*" Tom had returned to printing off sales orders and tallying up the number of pictures that should be requested by the mobile app prior to initiating the digital work process. Transforming the work back to paper gave Tom the ability to control the distribution of work amongst his peers in the shipping department. He became the primary shipping employee doling out work tasks and using the mobile application. As we experienced, Tom was willing to do more work keeping up both the paper and digital documentation because status was tied to the distribution of work and the production of data for management.

The remaining shipping employees were okay giving up the extra responsibility of data collection because the mobile application separated workers from physical tasks and introduced a level of monotony. The number of pictures needed per order ranged from 2, up to 100 or more based on the contents. One of the largest orders processed during our study required 96 pictures. This introduced a level of redundancy as Peter remarked when observing Tom's actions: "*He was pretty much in the same spot taking the same picture, but for like four or five different pictures.*" For workers, wanting more predictability and consistency in work did not mean creating repetition or slowing the process down. However, leadership was willing to sacrifice time for the creation of data because the pictures were not just about improving quality; they became an accountability tool providing oversight into the work performed by shipping employees.

5 DISCUSSSION

The blue-collar workforce provides an opportunity to reflect on what individuals want out of their devices at work and how technologies can support these aims within diverse contexts of use. Our findings illustrate how blue-collar employees in the shipping department responded to the introduction of data driven technologies including augmented reality and mobile devices. These tools changed the nature of work and reconfigured social relationships between workers, leadership, and technology. For the shipping employees, introducing mobile devices, shifted the value of work away from tangible outcomes of finished packages towards the production of data about those finished goods. As a result, workers had to renegotiate their roles and responsibilities. The actions of the shipping employees revealed a different interpretation of value from white-collar workers that led to their resistance in becoming a connected knowledge worker. We suggest that considering what makes work meaningful is one way to contend with the needs and values of different professional domains within the context of an organization.

5.1 A New Class of Hybrid Worker

Initially gaining access to mobile devices was viewed positively but hybridity changed the nature of work for shipping employees reorienting it around data production distancing workers from the tasks they enjoyed. The mobile app made it very difficult to respond to non-routine work that is common in small manufacturing operations [67]. Shipping employees required 'admin' permissions, as detailed above, to take pictures out of order or stop and start an order as needed. These actions introduced more complexity and higher-level knowledge work common to white-collar professions. Additionally, while taking pictures and using mobile apps were common skills for personal entertainment, these tasks were not valued the same way at work. Being behind the camera was viewed as inaction, even laziness, because employees were not moving and were stuck performing the same task over and over. In practice, the shipping employees ended up having to document up to 100 pictures per order slowing down the entire process. Managerial conceptions of consistency embedded in the software prioritized repeatability and repetitiveness which conflicted with the values of the shop floor employees. Creating data became a bureaucratic task that introduced more work and did not close the gap in information that employees sought with their newfound hybrid status.

In contrast, company leadership experienced major convenience gains because the intervention aligned with their conception of work as smartphone hybrid workers. Updates were provided to leaders via email notifications and text message alerts direct to their devices. When orders were completed, final reports were automatically generated and uploaded to the project management platform meaning leaders no longer had to scroll through hours of video to find quality documentation. The intervention held value for leaders because it produced data in a way that was easily accessible, interpretable, and sharable across their network. While white collar workers have adapted and conformed to primarily digital communication streams there still need to be alternatives for classes of people who may not have the ability to use or access digital technologies. In our study, having an automatically generated print-out of completed orders would have helped workers realize their version of a job well done. The focus of the process intervention to meet leadership expectations for data management neglected to automate the right kind of work for blue-collar employees which, as Grinter illustrated, is essential to developing successful workflow technologies [27].

However, paying attention to the power dynamics within the organization did reveal opportunities for hybridity to balance the scales of power between workers and leadership. This outcome runs counter to existing literature on automation that embraces deterministic perspectives [49,76]. The software solution granted each shipping employee access to order information through individual accounts on their mobile devices; any employee could take the lead role for packing and crating an order if they initiated the process (See Figure 3). Distributing work among the shipping employees upended traditional workplace hierarchies. Experience was no longer attributed to years working in manufacturing but rather technical prowess with computing devices. To be able to control and manage the tool, Tom, the most senior employee, created a paper-based shadow system that upheld existing social and power dynamics within the shipping team while creating a tangible outcome – a pile of paper – that held more meaning than the digital work queues. This form of data production took precedence negating the potential efficiencies of the tool. Tom also benefited from having a less strenuous role taking pictures, as an aging professional who was struggling to perform the kinds of manual labor necessary to pack and load an order. There is potential for data driven tech to support worker autonomy across a variety of skill levels, but it requires careful attention to the social human infrastructures in an organization not just the technical infrastructures [19,35].

In our study, the nuances between worker wants and needs and the values embedded in the technology only became apparent through extended use and time spent in the shipping department. Other researchers have suggested that developers be embedded on the manufacturing shop floor so they can overcome the cultural shock to create tools that respond to the real environment [32]. This approach is derived from concepts of creating 'living labs.' A consequence for all but the most resource rich manufacturers, who can develop custom solutions using participatory methods, is that technologies do not meet the demands of dynamic work and thus fail to create the kinds of efficiency gains or deliver the benefits of hybridity that they promise. There is a need to reimagine how to design technologies for a new class of hybrid worker in a way that supports and extends their capabilities rather than making them slaves to their own devices [47].

5.2 Designing for Meaningful Work

In HCI authors have pointed to the gap in designing for 'employee engagement and other emotional aspects of user experience' [57]. More recent work suggests we need to move beyond employee engagement if we are to truly understand and support worker experiences. Microsoft has proposed framing the conversation around "employee thriving, focused on being energized and empowered to do meaningful work in your role" [34]. Being engaged at work is not the same as being empowered or energized. In our study, employees had a high level of engagement with the mobile application, but it did not result in meaningful work leading to the creation of complex work arounds and ultimately, the lack of adoption. Meaningful work provides a lens that can address the difficulties of designing technologies for workplaces by contending with context specificity and variable user experiences. While meaningfulness overlaps with elements of user design, it is distinct in that it is an outcome of values and environmental context [40]. We know that meaningful work is important to cultivate a positive experience for workers [4,73], but we have not explored what it means to design technologies in a way that supports meaningful work for blue collar professionals. The impact of meaningful work has been tied to greater productivity, lower employee turnover and higher job satisfaction [3,5,55]. The difference is in how meaning is attributed to actions across different classes of workers [41,61,63]. Lips-Wiersma et al explored how meaningful work differed across pink-, white-, and blue-collar professionals [41]. The outcomes of their statistical analysis highlight that meaning can be traced to professional identities rather than solely individualist values [41]. Saari et al illustrate that meaning in blue-collar jobs is tied to autonomy, competence, relatedness, and beneficence [61]. These values are experienced differently from white collar workers and are directly affected by leadership and technology use [61]. For example, being connected for shipping employees was not dependent on internet access it was about physical interaction with coworkers, tools, and materials. Autonomy was associated with freedom of movement (i.e., not tied to a computer terminal or machine). Understanding what makes work meaningful for different classes of workers will help design technologies that automate the right kinds of tasks and align with different models of work essential to creating successful workflow technologies [27].

By prioritizing an entirely different set of values during the design process, meaningful work directly challenges ideas of scientific management that underpin our devices [26]. The shipping employees in our study wanted technologies to adapt to their environment but that took on different meaning apart from ubiquitous computing's understanding of the term [69]. To workers, blending into the environment meant not conflicting with their desire to be self-taught and self-sufficient. Most importantly, workers did not want to wear technology because it represented deficiency; not being able to do work without aid. Wearables detracted from how the shipping employees derived value and meaning from their jobs; it went against the professional identity of workers in a manufacturing environment where physicality is tied to masculinity. We saw this with the rejection of Google Glass. If we do not consider the values and characteristics that create meaningful work when designing new technologies, we risk increasing the employment gap as well as missing out on the potential to recruit other worker populations including females and minorities.

Extending our understanding of meaningfulness for blue-collar workers, our study points to the importance of maintaining a connection to the tangibility and physicality of work when designing new technologies. As we experienced the shipping employees derived satisfaction and pride from seeing their work go out the door. Valuing tangible outcomes also contributed to the creation of the shadow system as previously discussed. Paper documentation offered a physical permeance, a visible stack of papers at the end of week. In contrast, when studying a larger more automated industrial setting, Wurhofer et al found that "Production tasks are rather linked to negative emotions whereas administrative activities are experienced rather positive foster emotions like fun joy or pride" [72]. This reinforces that small and medium size manufacturers have different challenges of adoption that are context specific [12,75]. To contend with the variability of adoption and use across different scales of manufacturing we need to design technologies that preserve meaning. This move, to designing for meaningfulness, enables CSCW research to reframe what matters for automation in blue collar domains.

6 CONCLUSION

Our study illustrates the challenges that new technologies pose and how they are impacting organizations and blue-collar workers in industrial settings. Automation is still being approached in a very traditional sense, oriented towards efficiency and productivity which removed meaning from the work being performed by the shipping employees. Meaning for the frontline workers in our study was derived from elements including physical touch, tangible measures of success, and self-sufficiency which all have implications for automation design. In practice, the shipping employees developed a shadow system to circumvent the process intervention negating potential efficiency gains. Not only did automation change the nature of work and requirements for knowledge-based skills, but it displaced the satisfaction workers derived from performing physical tasks. These findings diverge from narratives that position technology as the central element in creating more desirable 'better' jobs. Additionally, factors that conflicted with blue-collar values included consistency, predictability, and autonomy. These concepts were intertwined with managerial ideas of control that surfaced as blue-collar workers were equipped with new digital tools. A part of CSCW is about contending with the friction between organizational goals and individual norms to create experiences that support people through technology. We need to continue to expand our own ways of understanding different values and practices by drawing on concepts like meaningful work to develop technologies that embrace the diversity of human experience.

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