OUT OF TOLERANCE: WORKER VOICE IN THE DIGITAL FACTORY

Working Paper - MIT Open Learning Workforce Education Project
(please do not cite or circulate without permission)

Jenna Myers
jemyers@mit.edu
PhD Candidate, MIT Sloan School of Management

CONTENTS

EXECUTIVE SUMMARY

For decades, surveys have shown that workers want more opportunities to directly participate in decisions that affect how they work and how they might improve the performance of their organizations, especially by providing input into how new technologies are used in the workplace. Advancements in technology are perhaps the clearest example of how the range of issues at the workplace today is expanding, as new technologies create changes in the task structure of workers and increase surveillance over workers,i which can give rise to workplace disputes.

However, a new set of digital, networked technologies, sometimes referred to as part of "Industry 4.0" or "smart factories," have two features that complicate worker voice. First, these digitally-enabled technologies, including robots, sensors, and artificial intelligence, can be continually modified with low or no additional cost, since they do not rely on capital investments in additional hardware or expensive consultation to customize features and settings to the firm. This continually changes their use in the workplace with resulting impacts on workers. Second and relatedly, this continual modification can necessitate a long-term relationship between third-party technology vendors and firms, including long after the technology is deployed

and in use, as vendors provide ongoing customer support and release periodic technology updates. These third-party vendors are not covered under traditional bargaining agreements and are not accounted for in employee involvement practices.

This case study explores the results of a longitudinal, qualitative study of when and how frontline workers have input into the ways digital technologies are used at MetalWorks (a pseudonym), a small machine tool shop that implemented a digital production monitoring system with MachineTech (a pseudonym), a start-up technology vendor. The installation began in January 2018. The MachineTech system used highly visible tablets at each connected machine that displayed graphics and numerical data, including the machine's current and average production cycle time, hour-by-hour parts production, and utilization. MetalWorks managers and engineers had access to a colorful dashboard that displayed the real-time status of each tablet, and MetalWorks chose to display this dashboard on large monitors in the CEO's office and the engineering office. While MachineTech was largely a tool for managers, allowing them visibility into real-time production information across the shop to pursue process improvement, some machinists found MachineTech's capability of providing current and average cycle times to be useful in helping them manage their own production. However, MachineTech also intensified the machinists' tasks in minor ways that were not viewed by them as directly value-adding, including by requiring them to log in and out of each job and to categorize reasons why the machine was down for periods greater than five minutes.

After installation, a MachineTech customer support representative was assigned to work with MetalWorks resolve issues and explore new use cases. During this time, changes to the technology occurred under a user-centered support model. This involved an indirect, manager-mediated voice channel from machinists to the vendor customer support team. Under this model, machinists successfully used voice to achieve a resolution on minor issues related to technology use, such as those related to the ease of use, accuracy of data, and customizable data entry. These resolutions were achieved when the MachineTech customer support representative changed a setting or flexible feature of MachineTech, such as the categories used to catalog machine downtime. Under this model, machinists were unsuccessful in using voice to achieve resolutions on major issues related to nature of the technology, such as those related to surveillance and access to data. These issues required programmable solutions to the technology that were more difficult and time-intensive to implement.

In the subsequent ten months after the MachineTech installation, worker voice occurred under a different model—user-focused design. This involved a direct, though infrequent, voice channel from machinists to the vendor product team. The transition from the user-focused support model to the user-focused design model occurred after a product lead with user-centered design experience was hired by MachineTech and began conducting shop floor visits with customers during which the MachineTech product team met with managers and interviewed machinists directly. During this period and through this direct channel, machinists successfully used voice to achieve a resolution on major issues related to the nature of the technology, such as those related to surveillance and access to data. These issues required programmable solutions that the MachineTech product team prioritized for development. However, during this period, machinists did not successfully use voice to achieve a resolution on all of their concerns. Issues that were not raised during the MachineTech shop floor visits followed the same process as they had before.

This case shows that third-party vendors play an important role in reinterpreting and prioritizing technology change issues in ways that affect worker voice. In particular, effectiveness of worker voice around such technologies may depend on the type of channel for worker voice that exists between workers and third-party vendors. When workers have direct vendor channels for worker voice, they can more effectively use voice practices to achieve technology improvements that expand the control of workers, including by softening surveillance and increasing worker access to data.

This case also demonstrates that worker voice can successfully occur in the absence of formal mechanisms for voice—like employee involvement practices and lean management techniques—and that it occurs throughout the lifespan of new technologies, long after the initial design and deployment phases. This dynamic will only grow in importance as flexible, digital technologies proliferate in the workplace, since these technologies can be continually modified with limited or no additional investment in equipment.

Finally, this case shows that the nature of the technology change affects whether and how workers' suggestions are successfully implemented. Under the user-centered support model, customizable solutions (e.g. changing a setting in a customer-facing dashboard) can be achieved through an indirect channel from workers to vendor customer support representatives. Under the user-centered design model, programmable solutions (e.g. time-intensive programming of a new version of the technology) can be achieved through a direct channel from workers to vendor product representatives. Programmable solutions are, in turn, diffused to additional firms that use the technology. This demonstrates the power of third-party vendors in prioritizing certain technology changes over others and highlights that workers and managers should have direct channels to both the customer support function and the product design function of such vendors.

INTRODUCTION

For decades, surveys have shown that workers want more opportunities to directly participate in decisions that affect how they work and how they might improve the performance of their organizations, especially by providing input into how new technologies are used in the workplace.ii,iii Advancements in technology are perhaps the clearest example of how the range of issues at the workplace today is expanding, as new technologies create changes in the task structure of workers and increase surveillance over workers,iv which can give rise to workplace disputes.

While union density in the United States is at historic lows, some firms have implemented employee involvement practices that can act as alternative mechanisms for worker voice around new technologies, including quality circles, self-managed teams, and technology champions.v,vi,vii These practices allow for frontline worker input into how new technologies are used, how associated work processes are redesigned, and how workers should be retrained, and they are used most intensively during the design and deployment phases of technology implementation.viii When used in tandem with complementary competitive strategies and human resource policies, these practices increase the gains that organizations receive from new technologies, as well as increase worker satisfaction and commitment.ix

However, a new set of digital, networked technologies, sometimes referred to as part of "Industry 4.0"x or "smart factories"xi, have two features that complicate worker voice. First, these digitally-enabled technologies, including robots, sensors, and artificial intelligence, can be continually modified with low or no additional cost, since they do not rely on capital investments in additional hardware or expensive consultation to customize features and settings to the firm. This continually changes their use in the workplace with resulting impacts on workers. Second and relatedly, this continual modification can necessitate a long-term relationship between third-party technology vendors and firms, including long after the technology is deployed and in use, as vendors provide ongoing customer support and release periodic technology updates. These third-party vendors are not covered under traditional bargaining agreements and are not accounted for in employee involvement practices.

While adoption of these digital, networked technologies is still low across manufacturing industries, we can learn from early adopters about best practices for involving workers in technological change and adjustment, as well as potential challenges that manufacturing companies will face during their digital transformations. One of these early adopters is MetalWorks (a pseudonym), a small machine tool shop that implemented a digital production monitoring system in 2018. This case study explores the results of a longitudinal, qualitative study of when and how frontline workers have input into the ways digital technologies are used at MetalWorks. We will see that machinists—the frontline workers using this new technology—were successful in using voice to achieve changes to the technology in some cases but not in others. Their success depended on the level and type of access that machinists had to the third-party technology vendor, as well as the type of technology changes that were required to address machinists' concerns (e.g., simply changing a setting or engaging in longer-term programming of a new version of the software).

PART 1: A FORWARD-THINKING MACHINE TOOL SHOP

MetalWorks is a family-owned machine tool shop located in New England, with fewer than 100 employees, about 40 of which are machinists. Other production-related functions include advanced finishing and quality assurance, which are supported by front office staff, sales, and engineering. MetalWorks uses CNC lathes and milling machines to manufacture highly precise metal and plastic components for industries including medical, aerospace, semiconductor, oil and gas, and emerging technologies.

MetalWorks is non-unionized and does not use common employee involvement practices such as quality circles, self-managed teams, or technology champions. It is representative of machine tool shops in lacking these formal mechanisms for worker voice. However, MetalWorks provides competitive wages, a flexible attendance policy, a profit-sharing program for all employees, and notable work-life benefits including a small on-site gymnasium, a garden, and training opportunities funded by state grants for non-work topics including sleep and English language lessons. Employees are provided annual cost of living wage increases and more frequent opportunities for merit increases based on manager discretion. The MetalWorks CEO described efforts he had made to keep the company culture open and inclusive:

> My door is open 95% of the time. I walk the floor multiple times a day, and machinists have the opportunity to address me. Now, I know that could be intimidating for some people, but I try to make sure that I'm approachable, and I think that's important for our entire executive team to understand – that they need to be approachable. We have idea boards, we have meetings where people can speak up, we have huddles. We try to create an environment to establish clarity and alignment, which is very difficult to do in our organization. Only then can you hold people accountable.

Early Conversations with MachineTech: In late 2017, managers at MetalWorks began conversations with a start-up technology company, MachineTech (a pseudonym), about installing a digital production monitoring system on its CNC machines. The installation began in January 2018. The MachineTech system used highly visible tablets at each connected machine that displayed graphics and numerical data, including the machine's current and average production cycle time, hour-by-hour parts production, and utilization. The screen on each tablet displayed a bright color that reflected the machine's production status and rate: gray (for machines not currently in operation), green (for machines making over 90% of their production goal), orange (for machines making between 80-90% of their production goal), or red (for machines making under 80% of their production goal). Production goals were specific to each job and were set by engineers based on actual past performance for repeat jobs or expected performance for new jobs. Engineers were excited to have this real-time data automatically collected, which was a significant improvement from the paper and pen method that they had used in the past, as this process engineer explained:

> Everything was done by paper and pen. We would record how much they were hitting as far as rates and parts an hour. Their information was getting lost in time. You would go out on the floor, and they would say, 'Things are running well.' You would take their word for it. Come to find out things are not running well. The biggest thing was, if a job was scheduled to run for three days, we just expected on that third day for it to be done. If it wasn't, then maybe that's when we would interact with that operator. We were beginning to realize how important it was to track that.

Managers and engineers had access to a colorful dashboard that displayed the real-time status of each tablet, and MetalWorks chose to display this dashboard on large monitors in

the CEO's office and the engineering office. Managers and engineers also had individual log-in access to a web-based dashboard with various timeline and reporting features about each machine that enabled further data analysis.1

While MachineTech was largely a tool for managers, allowing them visibility into real-time production information across the shop to pursue process improvement, some machinists found MachineTech's capability of providing current and average cycle times to be useful in helping them manage their own production. However, MachineTech also intensified the machinists' tasks in minor ways that were not viewed by them as directly value-adding. In particular, machinists were responsible for logging in and out of the production and set-up periods for each job on the tablets. Additionally, when the machine was down for longer than five minutes, the tablets displayed a pop-up screen that asked machinists to categorize a reason for the downtime, including tool change, break, and troubleshooting. Machinists also had the capability to enter data on the production of scrap (that is, parts produced with imperfections that had to be scrapped). Some machinists resisted categorizing downtime and scrap production, and these tasks were only occasionally enforced by managers.

These changes were significant, and managers recognized that it would take work to "get past the whole human element of, 'Why are you watching what I'm doing?'" as the CEO explained. He added that the company rolled out MachineTech on a limited number of machines that were "best performers" and that were operated by "our more progressive individuals that we felt would grasp and welcome this technology versus people that just would have a difficult time understanding it."

Growing Pains: Shortly after MachineTech was installed, machinists had the occasion to speak to managers about it because some of them noticed that the count of parts produced on the new tablets was higher than the number of actual parts produced. In some cases, the tablets were double-counting compared to real production. Due to machinists' sounding of this alarm, managers discovered that they needed to change the code that MachineTech relied on to count parts production, and they worked with the vendor to do so.

Throughout the first year after installation, machinists spoke up about this and other issues. Some were related to data accuracy, as the parts-counter issue had been, while others were related to machinists' use of the data or their dissatisfaction with completing redundant tasks (e.g., by recording scrap parts in both MachineTech and the MetalWorks ERP system). In particular, machinists perceived an atmosphere of surveillance had come to the shop. In part, they gestured to increased peer surveillance, because all machinists could see their colleagues' brightly colored tablets that indicated whether a machine was running smoothly that day or whether a machinist might be having problems. In part, they also referred to increased managerial surveillance, because they knew that managers now had remote access to continuous, real-time production information. These concerns persisted despite managers' continued reminders that MachineTech was in place to "measure the process," not the person. By this, managers meant that they used the technology to identify areas for process improvements, not to discipline or motivate individual machinists. The CEO was well aware of these dynamics, and said:

> If we're not reacting, if we're not communicating to [machinists], and they're not seeing the benefit, and I'm not talking

[1] Here forward, MetalWorks managers and engineers will be treated as members of the same group.

> about it at meetings on what it's done for us, then it could become a turnoff for them, and they're not paying as much attention to it as we'd like them to. So, I think the entire support network around it needs to be there.

Still, during this time, MachineTech was seen as an additional source of data for engineers and managers, but not as a useful tool for machinists. However, after about fifteen months after the MachineTech installation at MetalWorks, a shop floor visit by the MachineTech vendor began to change these dynamics, as the product designers showed interest in responding to machinists' concerns and ideas by releasing new features that lessened the atmosphere of surveillance and increased machinists' access to data on the tablets.

The next sections explore how machinists' voices were considered before and after these shop floor visits began. The beginning of each section provides an overview of the channel that existed between MetalWorks machinists and MachineTech vendor representatives during each time period, as well as providing an overview of the worker voice process in seeking technology changes to shop floor issues during each time period.

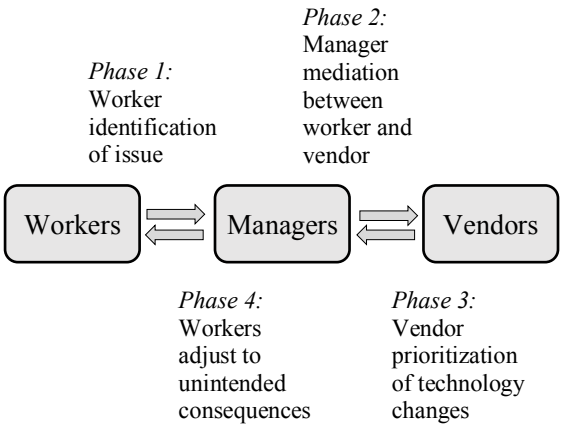
PART 2: USER-CENTERED SUPPORT MODEL

For the first fifteen months after MachineTech was installed at MetalWorks, worker voice occurred under a user-focused support model by the MachineTech vendor. This involved an indirect, manager-mediated voice channel from machinists to the vendor customer support team. During this period, machinists successfully used voice to achieve a resolution on minor issues related to technology use, such as those related to the ease of use, accuracy of data, and customizable data entry. The MachineTech customer support representative who was assigned to work with MetalWorks resolved these issues with a customizable solution, simply changing a setting or flexible feature of MachineTech, such as the categories used to catalog machine downtime. During this period, machinists were unsuccessful in using voice to achieve resolutions on major issues related to nature of the technology, such as those related to surveillance and access to data. These issues required programmable solutions to the technology that were more difficult and time-intensive to implement.

Successful Use of Worker Voice: Flexible Shifts Issue

Phase 1: Worker identification of issue:

During this time period, each opportunity stemmed from a machinist's assertion of a problem to a manager. Machinists asserted problems because they wanted to draw attention to an issue with the smooth or accurate operation of MachineTech or because they perceived undesirable conditions stemming from the use of MachineTech. Machinists had pre-existing communication channels with management through managements' regular presence on the shop floor, an open-door policy with the front office, and a well-developed culture in which machinists understood that any issue would "be heard" even if not necessarily resolved to the machinists' satisfaction. Machinists now



used these channels for raising issues related to MachineTech.2

One set of issues were raised by machinists who worked flexible shifts outside of the regular 7am-3:30pm first shift or the 3:30pm-12am second shift. Management allowed some machinists, with permission, to adjust the start and end time of these shifts by 30 minutes to an hour on a semi-permanent basis. But, MachineTech was programmed to rigidly allocate production time to each shift based on the regular schedule. This created annoyances for machinists who worked on flexible shifts. An engineer explained how one machinist in particular complained that MachineTech automatically logged out his tablet at 3:30pm, the official end of first shift, even though he regularly stayed until 4pm:

> [One machinist] would always complain that MachineTech would kick him out. [He's] is one of the [first shift] guys that could stay until 4pm. So, it kicks him out [at 3:30], and he had to go back and clock in again for that last half hour.

The engineer added that there had been similar complaints from machinists who started work prior to 7am:

> There's a few guys that are here at 5:30 or 5am, [and if they try to log in,] it logs in as unavailable or like a ghost operator. They couldn't actually clock in until first shift would start [at 7am]. So then there was a lot of complaints.

As shift-related issues raised by machinists accumulated, a manager relayed these issues to the vendor, triggering Phase 2.

Phase 2: Manager mediation between worker and vendor: MetalWorks managers met bi-weekly via videoconference with a MachineTech customer support representative to discuss issues, new use cases, and updates to the technology. Managers raised, at their discretion, issues they had noticed with MachineTech and issues raised by machinists. Sometimes, managers knew the specific feature of MachineTech that could be customized to solve the issue. At other times, they raised an issue as they understood it and then relied on the customer support rep to suggest solutions.

In the case of the flexible shifts issue, a manager raised the topic with the customer support rep because he had received the majority of machinists' complaints around their difficulties logging in and out. This manager directed operations at MetalWorks, and it was common for machinists to come to him with issues related to MachineTech and other issues. During a meeting with the customer support rep, he asked whether it was possible to change the shifts that were programmed into MachineTech, and then he explained the issues related to the current state:

> Operations director: Can we get rid of the shifts?
>
> Vendor customer support rep: All together?
>
> Operations director: Yes, I hate them . . . Some guys work after 3:30, so it resets. It drives me crazy. We don't gain anything from seeing the spread [of data across different shifts] . . . All we care about is machine uptime. We work with those guys to help them out, but seeing first versus second [shift] creates confusion and frustration.

Though the current state of shifts in MachineTech was a greater frustration to machinists as compared to managers, machinists' "confusion and frustration" had

[2] In fact, these communication channels and the relatively positive manager-machinist culture at MetalWorks led the MachineTech vendor representatives to identify MetalWorks as one of their more successful customers. It is likely that machinists' concerns would not have been translated to MachineTech without this preexisting culture and that limited changes, therefore, would have been made in response to machinists' concerns.

itself become a pressing issue for management, which prompted the manager to mediate between the machinists and the MachineTech vendor in order to resolve the issue. In this explanation, the manager indicated that his interests were aligned with the machinists—that removing the ability to analyze data by shift would not negatively affect managers' use of MachineTech. This manager mediation created the first filter between machinists' concerns and satisfactory resolutions, since managers could choose not to relay concerns to the MachineTech vendor or choose to relay concerns in a manner that suited managements' interests rather than machinists'.

Phase 3: Vendor prioritization of technology changes: After managers explained the issue, the MachineTech customer support rep attempted to respond. On rare occasions, the rep did not know the appropriate change to make to resolve the issue or whether a change was possible. In these cases, the rep noted that she would ask another customer support rep or a member of the MachineTech product team for a possible solution and then returned to the issue in a subsequent meeting.

In the case of the flexible shifts issue, the customer support rep responded immediately with two pieces of information. She first explained that the current version of MachineTech required that shifts be designated but that a new version of MachineTech was in development that would not require this designation. She then indicated that a workaround was available that would satisfactorily resolve managers' and machinists' issues:

> Vendor customer support rep: In the new [version of the technology], we're doing away with shift logic [but] that is going to be happening over the next 6-9 months . . . We could do something in the meantime [and] collapse your first and second [shifts] together . . . [into] one 24-hour shift . . .
>
> Operations director: That's fine.
>
> Vendor customer support rep: Then let's do it . . . Your operators, from their perspective, aren't going to feel a shift change . . . If you were a brand-new customer, I'd be more nervous about making a change like that, but you guys are pretty clear about what makes sense and functions out on the floor.

In this exchange, the customer support rep prioritized possible technology changes in two ways. First, she prioritized possible technology changes based on managers' prior experience with MachineTech, indicating that she might suggest different solutions for a "brand-new customer" versus for managers at MetalWorks, since they were experienced users of the technology. Second, the customer support rep distinguished between a customizable solution (creating one 24-hour shift by changing a setting in the customer-facing dashboard) and a programmable solution (removing the requirement to designate shifts through the time-intensive programming of a new version of the technology). In her role in customer support, the rep implemented customizable solutions where possible and relayed managers' concerns to the product team when a simple customizable solution did not yet exist. The customer support rep said that long development time required the MachineTech product team to prioritize programmable solutions that would benefit the majority of their customer base:

> We want to make sure we're . . . looking at what's best for the industry, what's best for the majority of our customers. A lot of customers have very custom requests of us . . . that our product team [does not find] very actionable because of the fact that they only impact one or two customers. It's very hard to justify spending three months of development on it, instead of on something that all of the customers need.

Prioritization by the vendor created the second filter between machinists' concerns and satisfactory resolutions, since the vendor could

choose which concerns to address and the nature of the solution.

Phase 4: Workers adjust to unintended consequences: While some changes required more involved programming by the MachineTech product team, the customer support rep helped managers find customizable solutions for many of the concerns that managers raised during the bi-weekly customer support meetings. After a change was made, managers sometimes remembered to update machinists on the change, particularly those individuals who had originally raised the issue. However, this communication was done in the normal course of the workday and did not always reach all machinists who used MachineTech. Additionally, changing one feature sometimes resulted in other, unintended changes, which created confusion.

In the case of the flexible shifts issue, moving from two shifts per day to one 24-hour shift per day changed the visual appearance of the production progress on machinists' tablets. On the tablets, production was indicated by a virtual ring that gradually closed as actual production approached the production goal. When first and second shifts were combined, the tablets showed that machinists on first shift produced only about half of the daily production goal rather than showing that they had completed 100% of the shift's production goal. The operations director had not foreseen this visual change, though some machinists had asked him about it:

> [Before,] if there was an hour left on the shift . . . this [ring] should be almost [closed]. Instead they're [not even half closed when first shift ends]. I didn't even think of it when we [made the change] . . . but it shows [that machinists] are paying attention [since they mentioned the change]."

Because machinists were not always kept thoroughly informed, they sometimes did not know whether or how their concerns had been addressed. In some cases, they unintentionally reversed or overrode the change that managers and the vendor had made, which extended the time and effort it took to solve the original problem.

Unsuccessful Use of Worker Voice: Tablet Color Issue

For the flexible shifts issue, the MachineTech customer service rep used a customizable solution (creating one 24-hour shift instead of a first and second shift) to successfully resolve the issue. This resolution occurred through an indirect channel from machinists to managers to the vendor, after machinists voiced concerns about logging in and out during shift changes. However, when a customizable solution was not available, machinists were not successful in receiving a resolution in response to voiced concerns. This occurred in the case of the tablet color issue.

Because MachineTech's main function was to track production in real-time, each monitored machine was fitted with a tablet that was placed so it was highly visible not only to the machine's operator but to other machinists, to the engineers and managers who sat in a glass-windowed office adjoining the shop floor, and to anyone else walking through the shop floor. The entire face of these tablets displayed a color that corresponded to the machine's progress on the production goal set by engineers. Some machinists had general concerns about their production being monitored and tracked in real-time, but the most common concern of the machinists that I shadowed was the visibility of the tablet's color.

One machinist said, over a year into his use of MachineTech, "I always like to keep my screen green. The others will say they don't pay attention to it, but they do." As he experimented with entering scrap material, a task he had not done many times before, he

accidentally entered a number for the scrap he had produced over the course of the entire production run, rather than only the scrap he had produced that day, which immediately turned the tablet from green to red. A few minutes later, the operations director came to ask what had happened. After a brief exchange, the operations director told the machinist that he should be putting scrap numbers in at the end of the day, in particular because the manager was concerned he had not ordered enough material for this job. The machinist said, "You understand why people are sensitive about putting real numbers in?" The operations director, half-smiling, said, "I don't understand it. I hear you telling me, but I will never understand it." A different machinist on the night shift said that others felt similarly negatively towards the colored tablets, saying, "The first couple weeks [after the tablets were installed], a lot of guys would turn it so they weren't looking at it." However, not all machinists felt this way. One younger machinist referred to the tablet unprompted: "It's cool that we can see it, so we know if we're behind. Right now, I'm catching up [from being in the red], so it's orange. I like that it's different colors." Managers knew of machinists' negative perceptions of MachineTech. They were also aware that many machinists did not enter scrap production numbers (or machine downtime reasons) into MachineTech because there was no associated data for these factors in the MachineTech dashboard. However, enforcing machinists to engage in comprehensive data entry was a priority often overlooked by managers on the hectic shop floor, and machinists could not access such data themselves, so they saw no intrinsic motivation to enter it.

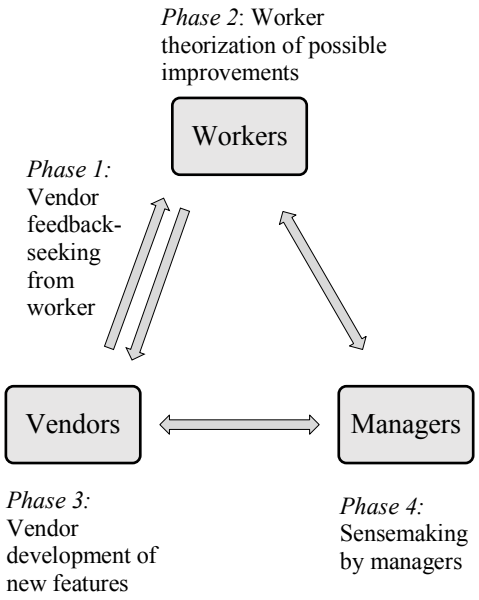
The majority of the machinists found the tablet colors stressful, even if they found the numerical display to be useful in showing average and current cycle times. Some voiced their concerns to managers, as the first machinist did (Phase 1). Yet, while managers relayed this displeasure to the MachineTech customer service rep during the bi-weekly check-in meetings as a way to update the rep on machinists' acceptance and use of MachineTech by the machinists (Phase 2), they did not discuss technical solutions to the machinists' concerns since there was not a setting that could be readily customized to change how colors were displayed on the tablets (Phase 3). Instead, managers occasionally spoke about holding additional training to remind the machinists of the importance of the data that was being collected.

Issues could be stalled and result in an unsuccessful use of worker voice in any phase. In the case of the tablet color issue, though workers identified an issue with the colors (Phase 1) and managers mediated between workers and the vendor by raising the concerns (Phase 2), the managers did not frame the issue as a problem that they wanted solved, and the customer service rep did not have a customizable solution, so the issue was stalled in Phase 3.

PART 3: USER-CENTERED DESIGN MODEL

In the subsequent ten months after the MachineTech installation, worker voice occurred under a different model—user-focused design. This involved a direct, though infrequent, voice channel from machinists to the vendor product team. The transition from the user-focused support model to the user-focused design model occurred after a product lead with user-centered design experience was hired by MachineTech and began conducting shop floor visits with customers during which the MachineTech product team met with managers and interviewed machinists directly. This change was crucial in transforming the process by which machinists' opinions and issues were incorporated into the technology. During this period and through this direct

channel, machinists successfully used voice to achieve a resolution on major issues related to the nature of the technology, such as those related to surveillance and access to data. These issues required programmable solutions that the MachineTech product team prioritized for development. However, during this period, machinists did not successfully use voice to achieve a resolution on all of their concerns. Issues that were not raised during the MachineTech shop floor visits followed the same process as they had before.



Successful Use of Worker Voice: Historical Data Issue

Phase 1: Vendor feedback-seeking from worker: This time, rather than each opportunity stemming from a machinist's assertion of a problem to a manager, opportunities stemmed from a MachineTech vendor representative seeking feedback directly from a machinist. On two occasions during this time period, representatives from the MachineTech product development team asked to visit MetalWorks to speak with engineers and managers about their use and opinion of the technology. They then asked to briefly circle the shop floor to speak with multiple machinists on their use and opinion of the technology. They timed these meetings to overlap with the shift change to be able to speak to machinists on both first and second shifts. The product team reps asked each machinist open-ended questions including what they found most useful about MachineTech, as well as what they did not find useful and what they would like added or changed.

One of the product team leads said that he had prior experience in user-centered design and that he had started these customer visits after being hired by MachineTech. Upon arriving at MachineTech, the lead asked the other product designer how many customers he had visited: "[The other designer] said, 'None,' and I said, 'Pack up whatever you've got, and we're going to a client tomorrow.'" This lead designer derogatively characterized the current version of the product as being "designed by engineers," and he encouraged the other designer to question the assumptions of the product engineers by talking with the end-users of the technology – both machinists and managers.

Importantly, MetalWorks engineers and managers supported these visits. The MachineTech product team lead said about his second visit:

> We went to MetalWorks a couple weeks ago and told them we only needed an hour, but we ended up being there for two and a half. They kept saying, 'Did you talk to this person, did you talk to [that] person?'

During these customer visits, the product team reps asked open-ended questions that encouraged machinists to share their opinions and to look beyond what currently existed to what might be possible. This triggered Phase 2.

Phase 2: Worker theorization of possible improvements: In this time period, rather than managers mediating between workers and the

vendor, these vendor shop floor visits allowed for workers to state their thoughts and concerns about MachineTech directly to the vendor in their own words. This removed the first filter between machinists' concerns and satisfactory resolutions that had existed before.

During the first visit by MachineTech product team reps, two machinists raised the issue of wanting to see historical data from past shifts. One machinist said:

> It would help if we had the average, the best run, and the current run, or a way to compare, so you know if you feel good today or are having a shitty day and need to know why. The cycle time is driving that information.

The other machinist similarly stated that historical data would be useful for problem-solving—a benefit to machinists that had thus far been overlooked as a function of the technology:

> So, today, if you're having problems and can't remember how you ran two days ago, you can compare. I know [operations director] can see the breakdown—I want to see a general graph [to see that] yesterday was good around lunch time, today, it's lower… It would be nice to see that.

An engineer had been present during the MachineTech visits, so the machinists did not share these ideas simply due to the absence of management. Instead, MetalWorks managers and engineers were pressed for time during their day-to-day interactions with machinists, so these interactions typically focused on particular production problems that did not facilitate worker theorization of new possibilities.

Phase 3: Vendor development of new features: The MachineTech product team gathered feedback from machinists at MetalWorks and their other customers over several months. The customer service rep said that product development took an additional several months due to the complicated programming that needed to be done:

> I find that it's hard for customers to understand, why would it take three to six months to upgrade all of your operator enhancement? Well, because it's a lot of programming . . . These development efforts are significant . . . We've talked about a host of enhancements. Now the team is kind of refining what the exact projects are going to be and assigning them and prioritizing them.

By taking this time, however, MachineTech addressed programmable solutions to machinists' concerns, rather than only proposing customizable solutions.

Two months before the new features were ready to be released, the MachineTech product team lead revealed that the historical data feature was going to be added as part of a suite of operator enhancements. Not only would operators be able to see data from the prior shift or the prior day, but by searching for the product or work order number, they would be able to pull up data from a job that had run many months earlier. This was useful to MetalWorks machinists, who often ran jobs once per year or once every few years and had trouble remembering the details of each job's production run. The new features were released to customers who volunteered to try them. The product team lead was confident that MetalWorks would be interested in beta-testing these features, particularly since their machinists had asked for some of the new features: "They're so involved. If it doesn't work for them, it won't work for other companies."

Phase 4: Sensemaking by managers: While the new features of MachineTech were under development, MetalWorks managers continued to meet with MachineTech customer support and product representatives, during which time they had

discussions about the potential new features. Even though these features were added based on machinists' feedback, rather than managers' feedback, managers engaged in sensemaking around the problems that the changes would solve. This sensemaking centered on how the new features improved communication between managers and machinists or among machinists, thus improving efficiency, which was a key daily concern for managers. This allowed managers to construct for themselves a supportive stance towards the changes.

For instance, after hearing about the idea to expand access to historical data for machinists, a MetalWorks engineer reacted with surprise and enthusiasm, suggesting that historical data would be useful to replace unreliable communication across shifts:

> That's actually a damn good idea. I'm impressed . . . [Right now,] when they come in, they'll just look at the shift before them and say, 'Okay, how many scrap did [last shift] have?' If we're averaging 5-8 scrap a day [and] if they see 30 scrap [and the prior machinist doesn't leave a note,] then they start . . . asking around, 'Hey, did so-and-so have a problem? Did they leave you a note rather than leaving the note for me?'

A MetalWorks manager described another potential use for historical data by referencing her current practice of doing rounds on the shop floor, during which time she asked machinists about discrepancies in past data. This process was complicated by the frequency with which machinists completed jobs and required the manager to show machinists additional MachineTech data when she asked them a question about a past job:

> The guys on the floor, they don't remember every single work order – they run so many orders . . . [Right now,] I've got to show them [the data]. All right, four work orders ago, this is how it ran, this is who set it up. Oh, and then they're like – it comes back to them. They figure out, okay, this is what happened.

With direct access to historical data through MachineTech, this manager believed that machinists might more quickly identify the details of past issues.

Transformation of Unsuccessful to Successful Use of Worker Voice: Tablet Color Issue

Before the shop floor visits began, machinists had experienced an unsuccessful use of voice around the tablet color issue, since their concerns about the surveillance culture created on the shop floor went unresolved. However, it is worth revisiting this issue after the shop floor visits occurred. Due to the new process instigated by these visits from the MachineTech product team, a programmable solution was developed that successfully addressed machinists' concerns.

During the shop floor visits, the product team deliberately sought feedback from machinists on the tablet colors (Phase 1). They initially phrased their questions to solicit an understanding of how machinists reacted when their tablets changed from green to red or orange, as they did with this machinist:

> Vendor product team rep: What happens if it goes red or orange?
>
> Machinist: I turn it off [joking]. Sometimes, nothing you can do. You can't make it go green just to make it go green.

As the product team talked to additional machinists, they noted the emotional reactions they received when asking about the tablet colors. They gradually changed their questions to solicit additional affective reactions, as with this second shift machinist:

> Vendor product team rep: If it's red, it makes you feel...

> Machinist (with limited English proficiency): Bad [taps his chest over his heart]. It's hard for us, hard for machinists.
>
> Vendor product team rep: What do you look at first, or what do you look at the most?
>
> Machinist: First, color. Second, part ID, how many parts are made.

Through these comments, these machinists did not suggest particular improvements to deal with their negative feelings about the tablet color; instead, they openly voiced their opinions on a perceived negative aspect of the technology (Phase 2). At the conclusion of the visit, the product team lead walked out of the shop floor with the group and said to no one in particular, "The tool was not designed with the emotional component at all…"

Months later, before the new features were released, the product team lead mentioned his memory of this visit: "One operator at MetalWorks said, 'When it's red, it makes me sad.'" The product team lead said that MachineTech had designed their new beta version to reduce the visibility of the color (Phase 3), changing it from taking up the entire face of the tablet to a colored bar along the top of the screen. When the product lead discussed this change with MetalWorks managers and engineers, he indicated that one engineer had identified that this change would solve the motivation problem that some machinists experienced when working near red tablets (Phase 4).

> [An engineer] said that the operators lose all motivation when it's red. But when it's green, they work harder to keep it green.

While this particular change would not meaningfully change MachineTech's capabilities, the product team lead wanted to change machinists' perceptions of MachineTech from the negative emotions associated with the tablet colors to positive opinions of the utility that MachineTech might provide in accomplishing machinists' tasks: "We're making it more of a tool to help [them] do [their] job better." Further, this change did not reduce managers' visibility into the data since managers still had access to a brightly colored monitor displaying the real-time status of all machines in the shop.

Earlier, machinists' complaints around the negative effects of having highly-visible colored tablets did not successfully achieve a resolution because managers did not ask for a change to this feature of the technology, and the MachineTech customer support rep did not have a customizable solution to offer. In contrast, machinists' complaints around tablet colors during the shop floor visits did successfully achieve a resolution through the new user-focused design process led by the MachineTech product team, which developed a programmable solution to this issue.

CONCLUSION

In this longitudinal exploration of a family-owned machine tool shop implementing a digital production monitoring system, we have seen that worker voice operated through different processes depending on the nature of the channel between machinists and the third-party technology vendor, as well as the nature of the technology change. In the first fifteen months after MachineTech was installed, workers experienced an indirect, though consistent, channel to the customer support function of MachineTech. This channel was mediated by mangers, who met with the customer support representative bi-weekly to discuss updates and concerns. Issues that were communicated to the vendor and those that had a readily customizable technological solution were implemented, though workers needed to adjust to unintended consequences of these changes. With the foundation of a positive manager-machinist culture and regular communication between the two groups, worker voice was successfully used during this period to resolve minor issues related to technology use, though it was

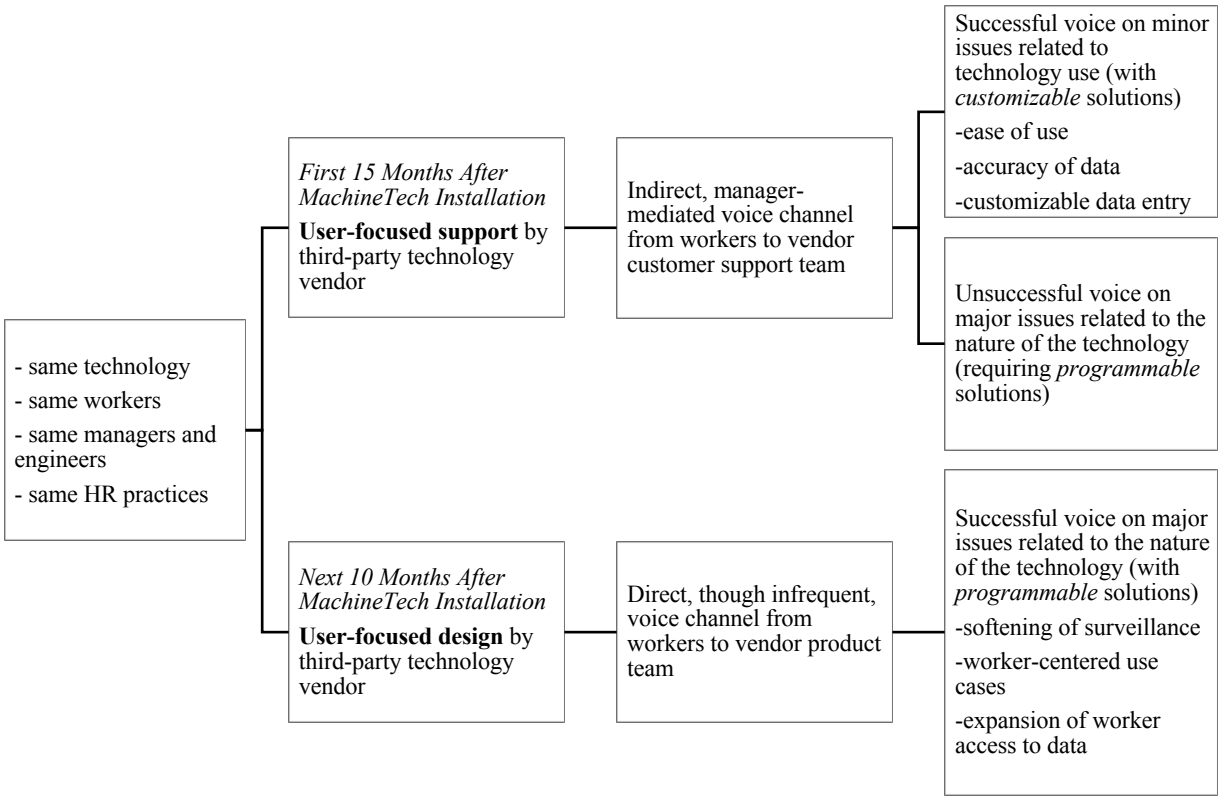
unsuccessful in resolving major issues related to the nature of the technology. In the subsequent ten months after MachineTech was installed, workers experienced a direct, though infrequent, channel to the product design function of MachineTech after the product team conducted several shop floor visits and solicited machinists' concerns. The product team developed programmable solutions to several major issues that were supported by managers after they engaged in sensemaking around the problems that these changes would solve. This resulted in softened surveillance and expanded access to data for machinists. See the diagram on the next page for a summary of these two processes.

This case raises several points for those interested in when and how frontline workers have input into the ways digital technologies are used in the workplace. First, existing formal mechanisms for worker voice, including collective bargaining agreements and employee involvement practices, involve policies and practices operating in the workplace. However, this case shows that third-party vendors play an important role in reinterpreting and prioritizing technology change issues in ways that affect worker voice. In particular, effectiveness of worker voice around such technologies may depend on the type of channel for worker voice that exists between workers and third-party vendors. When workers have direct vendor channels for worker voice, they can more effectively use voice practices to achieve technology improvements that expand the control of workers, including by softening surveillance and increasing worker access to data. Yet, even when workers do have direct access to third-party technology designers, these vendors have final control over technology changes that affect workers. For vendors, it is important to note that increasing the acceptance and use of new technologies depends on making the case for the utility of the technology not just for managers, but for the frontline workers that are the direct users. This case can be built by engaging directly with workers in their workplaces to uncover workers' opinions, challenges, and ideas firsthand.

Second, others have emphasized that worker voice around new technologies is successful when formal mechanisms such as collective bargaining and employee involvement practices, like technology champions, are used during the design and deployment stages of technology implementation. In contrast, this case demonstrates that worker voice can successfully occur in the absence of these formal mechanisms and that it occurs throughout the lifespan of new technologies, long after the initial design and deployment phases. This dynamic will only grow in importance as flexible, digital technologies proliferate in the workplace, since these technologies can be continually modified with limited or no additional investment in equipment.

Third, the prevalence of lean manufacturing and high-involvement work practices shows that scholars and practitioners alike have recognized that frontline workers have the unique ability to draw on their explicit and implicit knowledge about how work is done to provide suggestions of how new technologies can be modified to be used more effectively in the workplace. This case shows that the nature of the technology change affects whether and how workers' suggestions are successfully implemented. We have seen that customizable solutions (e.g. changing a setting in a customer-facing dashboard) can be achieved through an indirect channel from workers to vendor customer support representatives, while programmable solutions (e.g. time-intensive programming of a new version of the technology) can be achieved through a direct channel from workers to vendor product representatives. Programmable solutions are, in turn, diffused to additional firms that use the technology. Again, this demonstrates the power of third-party vendors in prioritizing

certain technology changes over others and highlights that workers and managers should have direct channels to both the customer support function and the product design function of such vendors.



This case also implies several notes of caution for proponents of worker voice. First, it shows that the presence of high road employment practices is likely an enabling condition for successful worker voice around digital technologies in the workplace, in particular because managers often mediate between worker concerns and technology solutions. Second, this study demonstrates the considerable power of third-party vendors over both managers and workers. Vendors can operate in ways that elude managers' interests, as well as those of workers'; in several instances, MetalWorks managers proposed several technology changes to increase workflow reliability that were deprioritized for development by the vendor. Third, the use of technology champions has been proposed as an effective form of worker voice during the design and deployment stages of new technologies. However, the relatively low cost and quick installation of some networked Industry 4.0 technologies can enable rapid and haphazard implementation within firms. In these conditions, neither workers nor managers can foresee potential issues or possess the relevant knowledge about what features of the technologies can be customized or programmed to solve these issues. Empowering workers throughout the lifespan of these technologies—not only during design and deployment—by expanding their awareness of technology capabilities and settings would likely enable workers to suggest more specific and useful solutions.

Future research could speak to the generalizability of these findings by studying

dynamics of worker voice around digital technologies in firms of varying sizes, industries, and competitive strategies. Larger organizations, in particular, might reveal different dynamics because the relationship between workers and technology vendors can be buffered by additional layers of management or by internal development teams. Additionally, this case has identified that the development and customer support functions of third-party vendors may be particularly important in determining channels for worker voice, and research is needed to test this proposition across a variety of technologies, vendors, and firms.

While the capability of managers and vendors to filter workers' concerns means that worker voice in the absence of formal mechanisms is precarious, this study shows that worker voice can sometimes be successful in achieving significant improvements to the ways digital technologies are used in the workplace, including by reducing surveillance and expanding worker access to data. Workers' influence on these issues will be increasingly necessary as networked technologies continue to proliferate across industries and collect data on an expanding set of workplace activities.

---

[i] Zuboff, S. (2019). *The age of surveillance capitalism: The fight for a human future at the new frontier of power*. Profile Books.

[ii] Freeman, R. B., & Rogers, J. (1999). *What workers want*. Cornell University Press.

[iii] Kochan, T. A., Yang, D., Kimball, W. T., & Kelly, E. L. (2019). Worker voice in America: Is there a gap between what workers expect and what they experience?. *ILR Review*, *72*(1), 3-38.

[iv] Zuboff, S. (2019). *The age of surveillance capitalism: The fight for a human future at the new frontier of power*. Profile Books.

[v] Adler, P. S., Goldoftas, B., & Levine, D. I. (1997). Ergonomics, employee involvement, and the Toyota Production System: A case study of NUMMI's 1993 model introduction. *ILR Review*, *50*(3), 416-437.

[vi] Litwin, A. S. (2011). Technological change at work: The impact of employee involvement on the effectiveness of health information technology. *ILR Review*, *64*(5), 863-888.

[vii] Osterman, P. (2006). The wage effects of high performance work organization in manufacturing. *ILR Review*, *59*(2), 187-204.

[viii] Miller, A., Christidis, A., and Kochan, T.A. (2018). "Engaging the Workforce in Digital Transformation." https://www.mercer.com/our-thinking/ career/engaging-the-workforce-in-digital-transformation.html.

[ix] Batt, R. (1999). Work organization, technology, and performance in customer service and sales. *ILR Review*, *52*(4), 539-564.

[x] Helper, S., Martins, R., & Seamans, R. (2019). Who Profits from Industry 4.0? Theory and Evidence from the Automotive Industry. *Theory and Evidence from the Automotive Industry (January 31, 2019)*.

[xi] Wellener, P., et al. (2019). *2019 Deloitte and MAPI Smart Factory Study*. Deloitte's Research Center for Energy and Industrials.