EMPLOYER-PROVIDED TRAINING IN TWO MANUFACTURING FIRMS

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(please do not cite or circulate without permission)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

Calls for employers to increase the amount of training they provide to workers have been increasing. Despite their frequency, it is rare for such calls to be accompanied by any consideration of the factors that make for successful employer-provided training, strategies to help employers design successful training programs, or a discussion of the organizational and occupational challenges inherent in providing training. This case study begins to address these questions by providing a deep window into the training provided to entering and incumbent workers in two manufacturing firms, MetalWorks and ElectriCo.

MetalWorks is a small contract manufacturer of precision machined parts for industries including aerospace, medical, and semiconductor. It is a family-owned company with a reputation for a being forward-thinking industry leader. Yet, as a small and dynamic company, MetalWorks faces challenges inherent in designing and executing training. Most entry-level training at MetalWorks is informal but requires a great deal of time from expert incumbent workers. The training experience is quite variable based on the competence, patience, and approach of these incumbents. The company has attempted to formalize training but faces challenges stemming from its complex product mix, the differing priorities of management, and the simple fact that, in a small firm, dedicating more human capital to training means taking it from production. In the

absence of a more formal system, certain individuals take on undue responsibility for training. They learn how to train "on the fly," and the variability in the system still lead to uneven results. There are also challenges in training incumbent workers to improve their skills and prepare for advanced technologies, which are exacerbated in the low-support environment of the night shift.

The second firm, ElectriCo, is a multinational defense contractor producing electronic systems. Workers at one establishment of ElectriCo designed an intensive formal training program that was later recognized and awarded by ElectriCo headquarters for its success. ElectriCo also sponsored a short-term training program at a local community college that acts as a feeder for its entry-level workforce. ElectriCo is intensely involved in the program to ensure that the students are learning skills specific to the company's needs. It is challenging to ensure that the program balances the needs of the students, the college, and the company, which is necessary when companies take training from inside the firm to external training providers. Even graduates of the college do several weeks of internal training at ElectriCo, progressing from practicing individual skills on mock products and software to performing multiple complex operations on real products with decreasing levels of supervision. Incumbent workers who need retraining experience particular challenges when learning to use automated equipment. Operating this equipment and the associated computer programs can be more challenging than computer-literate supervisors might assume. Cultural and managerial challenges can also limit the effectiveness of on-the-job training that takes place after trainees complete the formal internal training. As at MetalWorks, a lack of supervision on night and weekend shifts creates difficulties for operations across shifts. MetalWorks and ElectriCo can illuminate some of the factors that influence the design and approach of employer-provided training in manufacturing, because they differ in size and organizational structure. When considering how employer-provided training should be designed and maintained, managers should consider straightforward organizational factors such as size, ownership, and business model, but also whether the company has the ability to partner with local educational institutions, how employees are empowered to provide value to the firm, and whether work is organized across multiple shifts.

MetalWorks and ElectriCo also differ in the occupations they employ, with MetalWorks employing machine operators and ElectriCo employing microelectronics assemblers and inspectors. Occupational differences also affect the design and approach of employer-provided training, and managers should consider the following:

- The relative skill mix – whether the occupation is generally low, medium or high skilled, which affects how much ongoing training and development workers will need and what career paths should be developed as part of the training program
- The importance of knowledge vs. skills to the occupation – which has implications for how content should be delivered and how long the training period is likely to last

- Time to proficiency and time to mastery – which affects where training can take place, whether trainees can contribute to valuable work on real product, and how long the training period is likely to last
- The characteristics of the labor pool – what challenges exist in the likely pool of workers and how the organization can help address them rather than blaming the individuals
- Occupational meaning – how workers typically come to the occupation and
  what meaning it might hold for them as
  related to their families and their long-term career lives, which can provide insight into how trainers and companies can motivate trainees

It is important to note the variation that exists within the manufacturing sector and across industries. In particular, different industries have different regulatory environments and respond differently to economic and technological developments. These factors deeply affect how employer-provided training can and should be designed to benefit both employers and workers.

INTRODUCTION

Calls for employers to increase the amount of training they provide to workers have been increasing. These calls are coming from those who point to perceived "skills gaps" and believe that employer-provided training is a rational response by firms having hiring difficulties. They are coming from those who are pessimistic about technological change and believe that workers need to be trained to work with automation or to be retrained into occupations not yet affected by it. They are coming from those who question the value of American education and the work readiness of both high school and college graduates. Despite the frequency of these calls—which are drawing a response from some employers, notably including Amazoni—it is rare for such calls to be accompanied by any consideration of the factors that make for successful employer-provided training, strategies to help employers design successful training programs, or a discussion of the organizational and occupational challenges inherent in providing training. This case study begins to address these questions by providing a deep window into the training provided to entering and incumbent workers in two manufacturing firms.

Part 1 describes the mostly informal training that exists at MetalWorksii, a small contract manufacturer of precision machined parts for industries including aerospace, medical, and semiconductor. MetalWorks is a family-owned company with a reputation for a being forward-thinking industry leader. Yet we will see the challenges inherent in designing and executing training in such a small and dynamic organization. From a vignette of "Tara," a high school student doing a co-op at MetalWorks, we will see that most entry-level training at small manufacturing firms is informal but requires a great deal of time from expert incumbent workers. The training experience is quite variable based on the competence, patience, and approach of these incumbents. We then hear from "Tim," the Director of Operations at MetalWorks, about prior attempts at formalizing operator training. The company's challenges stem from its complex product mix, the differing priorities of management, and the simple fact that, in a small firm, dedicating more human capital to training means taking it from production. We also hear from "Josh," a young MetalWorks operator that has informally taken on training responsibilities in the absence of a more formal system. Josh learned how to train "on the fly" and has developed some useful diagrams of tool paths and part dimensions that assist trainees. But, the variability in the system still lead to uneven results. Then from a vignette of "Dave," a night shift worker, we see some of the challenges of training incumbent workers to improve their skills and prepare for advanced technologies. These challenges are exacerbated in the low-support environment of the night shift.

Part 2 describes the training process for microelectronics assemblers and inspectors at ElectriCo, a multinational defense contractor, and a community college boot camp training program that is supported by ElectriCo. Only one establishment of ElectriCo is considered in this case study, and the training described is particular to a limited set of front-line positions in that establishment. We will see how workers there designed an intensive formal training

program that was later recognized and awarded by ElectriCo headquarters for its success. From a vignette of "Haley," a young single mother, we learn about the short-term training program that ElectriCo sponsored at a local community college. ElectriCo is intensely involved in the program to ensure that the students are learning skills specific to the company's needs. It is challenging to ensure that the program balances the needs of the students, the college, and the company, which is necessary when companies take training from inside the firm to external training providers. We then hear from "Emma," a graduate of the community college program who was allowed to revamp ElectriCo's internal training program. Even graduates of the college do several weeks of internal training at ElectriCo, and Emma designed a curriculum that transitioned trainees from practicing individual skills on mock products and software to performing multiple complex operations on real products with decreasing levels of supervision. From a vignette of "Sharon," an older incumbent worker at ElectriCo, we see some of the challenges that incumbents can face when learning to use automated equipment. Operating this equipment and the associated computer programs can be more challenging than computer-literate supervisors might assume. Finally, we hear from "Anita," another incumbent worker being retrained for a new position at ElectriCo. Anita experienced on-the-job training under different supervisors, and we see how cultural and managerial challenges can limit the effectiveness of this stage of training. We also see again that a lack of supervision on night and weekend shifts creates difficulties for operations across shifts.

See the box below for characteristics of the two firms.

Company Descriptions

	MetalWorks	*ElectriCo*
Description	Machine tool shop providing custom precision parts	Defense equipment, electronics, and services provider
Size by Employees	<100 employees	>30,000 U.S. employees
Size by annual sales, 2018	>$12 million	>$20 billion (globally)
Business model	Family-owned, profit sharing model used	Multinational defense contractor
Industries served	medical, aerospace, semiconductor, oil and gas, robotics, emerging technologies	defense and cybersecurity

Part 3 discusses an assumption that organizational and occupational characteristics affect the ways that employers deliver training. This section compares and contrasts the organizational features of MetalWorks and ElectriCo, as well as the occupational features of machinists and microelectronics

assemblers. For example, we see that occupations' "time to proficiency" affects how soon new workers can be integrated into regular operations and thus has implications for whether training can take place on-the-job or whether it should be delivered in a separate environment. Given the limited number of organizations examined here, Part 3 merely provides propositions for further study. But, propositions of this type will be important to build upon as employer-provided training continues to be a focal point for those interested in the future of work.

PART 1: TRAINING OF ENTRY-LEVEL AND INCUMBENT WORKERS AT METALWORKS

Informal training for entry-level workers

An unusual opportunity. Tara Spellman was a typical junior in high school—dreading taking her upcoming SATs, and balancing her time between school, spending time with her boyfriend, and her part-time job. At least the job was going well. It was an unusual job for a high schooler—a co-op at a local machine tool shop, MetalWorks, that had been arranged for Tara through her school. Tara had connected with the company a few years ago through a family friend, and her school had later brought a group of students to tour the facilities. In fact, Tara had been unofficially training for this job for a long time. As a student in the precision machine engineering program at a vocational technical high school in Massachusetts, Tara could do a co-op in a local business during her junior year that was related to her program of study. During her co-op, Tara spent two weeks at MetalWorks, learning new equipment and inspection techniques while making actual products, and then two weeks back at school, taking academic classes. The plan was to continue rotating between work and school every two weeks for the semester, and likely for the following academic year, while she applied for colleges and considered her next step after graduation.

Co-op structure and on-the-job training. Tara liked the work—"This place won me over [during our tour]. I wanted to learn [more of] what I'm learning in school and apply it." She spent her first few weeks working on MetalWorks' lathes, making simple parts that were in continual demand by MetalWorks' customers, meaning that MetalWorks' engineers had perfected the manufacturing process. This was also a good way for Tara to start learning about the culture and operations of the company. Tara rotated through additional machines in the subsequent weeks, and on a late spring Tuesday afternoon, she moved to work on a small Swiss CNC machine under the supervision of someone she knew well. Damien, the usual machine operator on this job, was on the advisory board of Tara's program at school, and she had occasionally babysat for his children. "Damien was a big push", she said, while unloading a few parts from the machine, since he encouraged her to apply for the MetalWorks' co-op position even before she had toured the

facilities. “Damien is a good trainer”, she continued. “He's not like the guys that will sit there and watch you, and then say, ‘Let me do that.’ He lets you get hands-on . . . And it's a lot of new things. Like comparators [(equipment for parts inspection)]. We have one at school, but they didn't let us learn on it. I learned more here on the first day than I did during my time in school.”

A challenge: parts inspection. It was time for Tara to do an inspection of one of her parts, for quality assurance purposes. She took the part, a complex screw-like piece, into the quality room, which housed several quality assurance technicians and some of the more expensive inspection equipment at MetalWorks. To measure the smoothness of the metal finish on her part, Tara needed to use an inspection tool called a profilometer, which, when the part was loaded onto it correctly, automatically dragged a metal tip across the part to assess its smoothness. Tara had been having trouble loading the part into the profilometer. She asked for assistance from Will, one of the quality assurance techs. Will set aside his own work and joined Tara at the profilometer. He told her that the profilometer was set up with the wrong tip and helped her change it. “Do you see that metal notch? That should dip in. Don't push it all the way. Moving forward, let me do it for you. See the space?” He inserted the tip and then had her try it. “Take it off and put it back on. And that's a diamond tip, so be careful. It's $600 a piece.” Tara successfully inserted the diamond tip, but then struggled to center the tip on the side of her part that needed to be measured. Will assisted throughout this process.

Learning multiple methods. Fortunately, Tara only had to measure three additional dimensions, and she did these independently. However, the job required her to inspect one part for every fifteen that were produced, so she was back in the quality room before too long. By now, Will was out on the shop floor, and only one quality tech, Austin, was currently working in the room. Tara said hello to Austin and checked one dimension on her part with only minor assistance. But, it was time for the profilometer again. She said, “Now I'm really going to need your help, Austin, to check the finishes on the radius [using the profilometer]. This is the one that I seem to struggle with.” She tried on her own first and got a result that was unusually high. Austin, slightly absentmindedly, said, “It should be good.” But Tara responded, “I don't think that's right.” Austin looked closer at the way Tara had set up the profilometer, and he said, “The way I usually do this…”, manipulating the part and the block used to hold the part to the profilometer. Tara watched and said, “Oh, with the V Block and spinning it...” She tried, and Austin corrected her, “Get that diameter facing up.”

After another hour back at the machine, it was time for the profilometer again. Tara successfully set up the part and ran a measurement—3.62 micrometers. That wasn’t right. She tried again and got 4.22. She looked around the room, and a third quality tech, Brian, was now the only one in the room. Tara called over to Brian that she was getting "four

twenty two" on the profilometer. Brian paused, confused. Then he said, "Oh. Four point two two." He told Tara that anything under six was good. Even though the dimension was within acceptable tolerance, Tara still asked Brian to double check. “I don’t know if I’m off.” Brian took a look and told her that she had set up the part incorrectly. He said, “Lift [the tip] up, then return.” Tara said, “The centering gets me every time… Can you double check that my radius is on center?” Brian paused again, and then said, “I hope you don't mind that I cheat.” He took the block, and instead of eyeballing the placement of the part, he brought it under his microscope. “Here's how you check. Use everything to your advantage. All of these tools are at your disposal. Look straight down, and you can see exactly where you are.”

Tara’s vignette reveals the complexities of training entry-level machinists in a twenty-first century shop. Given that the majority of manufacturing establishments in the United States are of small- to medium-size, like MetalWorks, what we can learn from Tara’s experience is generalizable to a large part of an industry that has struggled to market itself to younger generations as providing promising careers.

While Tara is a high school student, MetalWorks’ training process looked similar for entering machinists regardless of age. For all new workers, multiple incumbent employees considered it their responsibility to assist and answer questions. This exposed new workers to multiple methods for the same skill, allowing new workers to adopt the methods that work best for them. Tara’s experience with the three quality assurance technicians demonstrates that incumbent employees have a variety of teaching methods and tendencies; Will verbalized his actions while showing Tara how to insert the diamond tip on the profilometer, and Austin mainly showed, rather than told. The supervising machine operators also had different training tendencies. Damien, unlike many of the operators, let Tara be more “hands-on”, and did not get impatient with her pace of learning. (Damien could often work on another machine while supervising Tara, occasionally checking on her and being available for questions.) Tara was also exposed to subtle occupational norms throughout the course of her training (measurements are verbalized as “four point two two”, not “four twenty two”). Importantly, we have also seen how Tara was originally connected to MetalWorks—through a close personal contact, Damien.

To summarize, these aspects of Tara’s experience are useful for understanding the informal, employer-provided training that is representative of many small employers of craft occupations:

- Most training at small firms is informal from incumbent employees.
- While Tara’s training process was informal and relatively unstructured, it required a good deal of time from helpful, expert incumbent employees.
- In this type of environment trainees’ experience is quite variable, depending a great deal on the competence, personality, and approach of supervisors and mentors.

Considerations in developing a formal training program: While MetalWorks has established partnerships with vocational high schools (like Tara’s) and with some

colleges, managers had struggled for years to develop a more formal internal training and onboarding program. The Director of Operations at MetalWorks, Tim, said:

> I've been pushing hard for formality. [Our CEO also] pushes for training, but it's our biggest weakness. The two companies I visited, and then they came and spend some time here – they were larger companies, but similar machine shops – they both have Directors of Training.

MetalWorks, as a small business, had not invested in a full-time administrative role for training. The option was now on the table, but management first needed to review their existing training resources and policies. During the most recent training effort several years prior, Tim, the human resources director, and several engineers had worked to detail learning objectives, training delivery methods, and a general structure to evaluate worker competencies. The learning objectives included hundreds of competencies for safety, lean management practices, and technical skills. These were each aligned with one of several delivery methods, including "OTJ, job shadowing, tech-based, cross-functional teams, simulators, coaching/mentoring, interim role, add responsibility, lectures/seminars, and experimental learning." One evaluation method that managers had suggested was a simple 2x3 typology: for both simple and complex jobs, operators might be qualified as competent in operating the machine, setting up the machine, and programming the machine, for a total of six technical competencies.

However, the company's challenges were not in understanding what employees needed to know, but instead how they could best deliver and evaluate these competencies.

Tim knew that MetalWorks faced several challenges in developing a structure for content delivery. First, the company's product mix was extremely variable. Thousands of different jobs had been completed over the past several years; some were run continually, while others only appeared once or twice a year. Some jobs had proven processes, while many were considered "R&D work". With this mix, it was difficult to track the existing state of workers' knowledge and to design a system to measure their learning. Tim had already pushed for changes in how the company organized work cells, seeking a return to the days when one set of workers focused on R&D work while another set focused on the jobs that had proven processes. However, he knew that this arrangement would limit how much operators learned on the job, since they would be seeing a smaller variety of work. Second, Tim has sensed a lack of understanding as to the purpose of developing a more formal company training program. When asked, managers variably named improving the onboarding process, the creation of standardized best practices, or the creation of a general learning culture as the main reason for developing more formal training. While all of these issues were recognized as important, managers' disagreement over the top priority for training made it difficult for them to grasp how best to tackle the enormous task of developing a sustainable training program. Third, Tim struggled with the belief that, as a small company, MetalWorks could not afford to dedicate spare resources to training. Those that were most qualified to

train or evaluate workers were also the most highly skilled and thus those that were most needed for production. As Tim put it, "Are you going to pay them to instruct when they could be getting work done? That's the problem." Because of these challenges, the decision to hire an administrative position to coordinate training was tabled.

To summarize, the company faced problems in developing more formal training approaches:

- Wide mix of products resulted in an unwieldy number of learning objectives and difficulties in evaluating worker competencies.
- Managers disagreed on the top priorities for training.
- Relying on incumbent workers to train pulled the most skilled workers off productive work.

Informal training from a trainer's perspective: Meanwhile, new workers were still joining the company and needed to be trained. For co-ops like Tara, as well as for new full-time employees with limited experience, the training process continued to be variable and depend greatly on the trainer. MetalWorks tended to use younger employees, those with fewer than ten years' experience, as trainers. One young trainer, Josh, became recognized as an effective trainer and was thus overburdened with training responsibilities.

> I used to like it more . . . It's been hard lately. I've trained I think fourteen people total [in the last year]. But it's different people with different questions, that's the good thing . . . I trained Tim a half-day for three or four days total. Mike, [I trained for] three weeks.

Because Josh learned how to train on the fly, he had developed his own techniques and priorities. His trainees appreciated the color-coded diagrams that Josh drew, which showed trainees which tool in the machine corresponded to which feature of the workpiece. Josh also learned to deliver information about company norms.

> [With so much practice, training] becomes more of a set way. If they deviate from [responding to my usual methods], I try something different, but most is like [delivering] a schtick – things you do, things you don't do. I go over basic things, like [how you handle] walking away from the machine on break. Yes, you can be a couple minutes late, but you shouldn't be. You can't be on your phone, but there are some exceptions.

This meant that Josh, as the trainer, determined how company rules should be interpreted, and he also was occasionally put in the unfortunate position of enforcing some rules. One trainee repeatedly used his phone during work hours, even after Josh explained not to.

> I told him about the phone [policy]. I said, [managers] don't allow it. Other people you may see [with their phones], but don't do it. I didn't say anything when I saw [him with his phone out] again. He'll just hide it from me [next time].

When new trainees first started on the job, Josh met with Tim, the Director of Operations, to update him on the trainees' progress. This training and socialization period took place from anywhere between several days and several weeks. After that, new workers were rotated to different departments and machine types based on their interests and abilities. Some might rotate every few weeks, while others

wanted to get comfortable on one machine for several months. While this generally meant that the most driven workers received the most opportunities to learn, this was not true for all workers, as we will see next.

To summarize, the company maintained an informal training system:

- Some workers shifted to spending more time on training.
- Trainers met with management to update them on trainees' progress.
- Because a formal rotation system with set time periods was not established, some workers built a range of skills and others did not. This led to high skill variability issues and corresponding work flow management complexity.

Challenges for incumbent worker training across shifts

Life on the night shift. Dave Caffrey was an unusual night shift machine operator. When he had the opportunity, he chatted as he worked, and his co-workers and managers at MetalWorks were familiar with the ins and outs of Dave's family life. In fact, managers had agreed to let him begin and end his shift a bit later than the others due to his family obligations. "My daughter has autism, so we homeschool her, and I come in a little bit later," he explained. He was grateful for the flexibility. It was his fifteenth year at MetalWorks, so he had built a good rapport with others at the shop. He had always been on second shift, though it was not a decision that came from preference but from obligation. "I need that 15% [pay] differential [that we receive on second shift]. I have four kids . . . and they are starting to say that they never see me. I tell them, 'I can switch to days, and then we won't have a house.'"

Dave removed a part from the machine and took it to a sanding wheel to smooth any imperfections. Given that he had a longer tenure at MetalWorks than many other operators, Dave also liked to comment on the way the shop was run and how things had changed over the years. "The CEO is big on 'leveraged labor', [where operators are] running more than one machine [at a time]. But you can't do that unless you take the secondary operations away—polishing, finishing. If they took [those] away, that would free up time we have to do other stuff . . . It's hard to keep up with. Maybe during the day it's easier, but night doesn't have a lot of support [from engineering or management]."

Challenges for learning. This lack of support worried Dave for other reasons. MetalWorks' management adopted the common attitude that second shift should be reserved for production of jobs that were simpler—high volume jobs that had been repeatedly run and posed few surprises. Dave said, "It can be tedious. I ran the [same] job for 8 months. I said to [management], 'If you don't switch me, I'm going to run into a wall or look for a new job.' . . . I wanted to do more job shop stuff, where you would make five parts here and there. I like to be challenged, seeing what's different and new. That's one thing I constantly fight with myself about being

on second shift. [Management] thinks second shift is just for production because there's no support [for the operators]. . . . But you've got to let people fail. [Let] me set up [a machine], and if I run into an issue, I'll stop and switch over [to another one]. Then I can learn what happened [and what went wrong] the next day."

Dave continued, "I need that [pay] differential, but it scares me, if something happens and I have to go somewhere else, and they ask me, 'Can you do this?', I'll have to say, 'No, I don't know that,' because I never learned. And if you don't do [more challenging tasks] all the time, you get slow at it . . . Maybe they could switch for a couple months and do a split shift, [so I could] shadow someone during the day. There are not many guys in their thirties like me. They're either young or are in their fifties, so MetalWorks is going to be losing the pool of talent in the next few years. It'll be drained. If you're not going to teach guys like me, who are you going to have?"

Shadow of the robotic future. Dave's time in the industry had spanned an interesting period. He learned machining on manual machines that required a hand crank to operate and the use of trigonometry to calculate the proper movements of the tools. He was now seeing some of the new robotic machines and digital technologies that MetalWorks had brought in over the past few years. He said, "It's scary for me, it'll be replacing what I do in about 10 years. My younger son wants to do this, and I said that's okay, but it's not going to be what I do. There'll be two guys, and all they'll be doing is, if something alarms, they'll see what's wrong . . . But for me, it's fun to watch [new technology developments]. I think I've got to keep up with the technology, so I continue to learn about it. Like 3D printing. It's fun to watch the videos on YouTube." Despite this curiosity and drive, Dave felt stuck in night shift and stuck in a schedule that allowed him to fulfill his family obligations. For him to receive training in more advanced techniques and new technologies would require more creative solutions than MetalWorks' typical informal mentoring system.

Dave's vignette demonstrates additional challenges that make incumbent worker training more difficult for firms than entry-level worker training. As a second shift worker, Dave had fewer opportunities to learn from either engineers or from more proficient workers, since these were concentrated on the day shift where more challenging work was performed. Additionally, Dave hinted at a looming challenge for many manufacturers – how to upskill workers to operate, troubleshoot, repair, and interact with new technologies. Dave was clearly an unusually motivated and curious employee, but his family constraints, combined with MetalWorks' lack of a structured training plan, prevented him from building his skills to handle more advanced work and to prepare for the ways his work would be changing as a result of more advanced machines.

To summarize, with an informal training approach, the major differences between work shifts affected skills acquisition for incumbent workers:

- Night shift work provided less training support, so skills of these workers were more limited
- An informal training environment where incumbent workers provide the training makes it difficult for all workers, especially the less-supported night shift, to get the training they will need on advanced technologies, such as robotics, now entering the workplace.

MetalWorks Summary: The box below summarizes the MetalWorks employees we've met and some of the training challenges each has faced. It also repeats the broader lessons we can draw from each topic.

Topic	*Workers and Managers*	*Lessons from their Stories*
Informal training for entry-level workers	Tara: High school co-op (two weeks at MetalWorks, alternating with two weeks at her high school). Learning from Damien, other operators, and three quality assurance techs. Excited for the chance to learn new equipment and techniques. Struggling with some skills but persisting to mastery.	• Most training at small firms is informal from incumbent employees. • While Tara's training process was informal and relatively unstructured, it required a good deal of time from helpful, expert incumbent employees. • In this type of environment trainees' experience is quite variable, depending a great deal on the competence, personality, and approach of supervisors and mentors.
Considerations in developing a formal training program	Tim: Late thirties, Director of Operations. Prioritized machine operator learning and training but struggled to find a more formal training system that could adapt to the operational and product constraints that the company faced. Met with trainers to learn new employee strengths and challenges.	• Wide mix of products resulted in an unwieldy number of learning objectives and difficulties in evaluating worker competencies. • Managers disagreed on the top priorities for training. • Relying on incumbent workers to train pulled the most skilled workers off productive work.
Informal training from a trainer's perspective	Josh: Early-twenties with half a decade of experience at MetalWorks. Informally responsible for training new lathe operators. Has trained fourteen so far, and is getting fatigued by the level of training needs. Develops new ad hoc training methods to respond to different trainees' needs, but could use help in learning how to train.	• Some workers shifted to spending more time on training. • Trainers met with management to update them on trainees' progress. • Because a formal rotation system with set time periods was not established, some workers built a range of skills and others did not. This led to high skill variability issues and corresponding work flow management complexity.

Challenges for incumbent worker training across shifts	Dave: Mid-thirties night shift worker with fifteen years' experience. Receives little support and few challenging jobs on the night shift. Eager to learn more advanced machining and excited by new technologies, but feels stuck on the night shift due to family obligations.	• Night shift work provided less training support, so skills of these workers were more limited • An informal training environment where incumbent workers provide the training makes it difficult for all workers, especially the less-supported night shift, to get the training they will need on advanced technologies, such as robotics, now entering the workplace.

To see some variation in the training process, including additional challenges of responding to automation through training, it is worth examining another organization, this time, a much larger manufacturer that we will call ElectriCo.

PART 2: TRAINING OF ENTRY-LEVEL AND INCUMBENT WORKERS AT ELECTRICO

Workforce training at the college

Challenges at school and at home. Haley Abbott was getting frustrated. She was in her fourth week of a ten-week "boot camp" training program for microelectronics at her local community college. It seemed that, every week, the instructor introduced a new set of skills that took hours of practice for Haley to pick up on. Haley had already learned how to lay down miniscule electronic components and attach them to a gold "coupon" with epoxy. And she had learned how to use machines to create bonds made of gold wire that connected these components and created complete electrical circuits. But now, the instructors were asking her to use small chisels and tweezers to remove damaged components and bad bonds without damaging the neighboring components that were sometimes sandwiched only a millimeter or two from her target.

Haley was a twenty-year old with an already-complicated life. She shared part-time custody of her son with her ex-fiancé, and she knew that her retail job would not provide the good life she wanted for herself and her son. At a recent tour of ElectriCo, she said as much to the HR professionals and factory managers who had organized the visit. "I heard about this [community college] program through my aunt, who's an engineering assistant [at ElectriCo]. I took the tour of the facility and liked it. I want to do this for my son and me. I'm a single mom, and I want to give him a better life."

An uncertain outlook. ElectriCo had hosted each cohort of boot camp students for this type of visit. The company had actually inspired the creation of the boot camp several years earlier and had donated equipment and old materials to the college. It also hired a majority of the boot camp graduates—or at least it had from earlier cohorts. The industry forecast

was changing, and ElectriCo would likely need far fewer new microelectronics assemblers and inspectors in the near future.

All about technique. However, back in the classroom, Haley wasn't concerned with her potential future employer; she just wanted to perform rework successfully. She was working under the instruction of a lab assistant, Andrew, who had worked at ElectriCo for a short time before joining the boot camp as a part-time instructor. Andrew directed Haley to a specific area of her coupon for rework. "Take off this [wire] tail without taking off the ball [that it's attached to]. There's two ways, with a tweezers or chisel. Then you tap without pressing it. Pressing will cause it to snap off. Use the front end of the chisel and hit low." Haley tried, but the ball came off as well as the tail. She tried again in a new area, again removing the ball as well as the tail. Andrew moved the coupon around under the microscope to find more wire bonds for her to practice with. "Do this with just the chisel." Haley protested, "I want my tweezers." Andrew said, "You won't always be able to fit your tweezers in there." Haley tried again, more successfully but inflicting some damage to the metal component on one side.

Andrew provided more instructions. "You don't want to snap the wire, just tap at the neck. Because here, there's a bit of damage now. Make sure your blade is level. You're doing it like this-", he said, holding the chisel incorrectly, at a bit of an angle. Haley took the chisel back and haphazardly did a few more wires, clearly not trying to be careful anymore. Andrew admonished, "Slow down. With the ball, try to flick it off, not scrape it off. Like a lever." He took over her materials and demonstrated, removing a couple of tails in very quick succession. The several other students watching him work through a computer display attached to the microscope could tell that he made this look quite easy, despite Haley's struggles. Haley smiled. "You know what Andrew? No one asked you." Andrew found more bonds for her and again had her try to do remove the wire without removing the ball. She was a bit better at it this time. He said, "Make sure [your chisel is] perpendicular. And you're [supposed to be] hitting it above the ball. Just push over, just tap it, to get the ball. Just pop it off." He showed her again. She said, "I can hear it, pop, pop." She tried again, this time doing it well. Andrew approved. "Nice. You got a little collateral from the chisel, because you weren't perfectly perpendicular. But that's it!"

The long training road ahead. Haley's difficulties with learning these new skills were not unusual. In fact, she was among the top performers of her cohort and had actually stayed late, along with a few other students, to further improve her skills that day. If her performance and attendance continued, she might be hired by ElectriCo for a full-time position at the culmination of the boot camp program. If this happened, even after completing these ten weeks of intensive training at the boot camp, Haley would spend her first month or two at ElectriCo in additional training. Several graduates of the boot camp had

redesigned ElectriCo's internal training program a few years ago, and Haley would experience this training in a separate room dedicated for that purpose, using actual product modules from the factory floor, as well as a mock version of the company's manufacturing planning software. She would likely move through this training on an accelerated pace, due to her boot camp training, and there was a small chance she'd be brought on as a direct hire with benefits. The chances for that were not good, however. Most entry-level assemblers these days were hired as contract workers, without benefits and with an indeterminate trial period before being considered for transfer to a direct hire. So, Haley's future was still quite uncertain.

Haley's vignette demonstrates another, less common, type of workforce training. While Tara—the high school co-op student at MetalWorks—had some formal training at her vocational school, the bulk of her training took place on the shop floor of MetalWorks, through repeated experiences and interactions with competent incumbent employees. Haley, on the other hand, was learning similarly specialized and detailed work, but in a classroom environment, and with less guarantee of a secure, paid job—at ElectriCo or elsewhere.

In fact, the community college boot camp program owed its existence to ElectriCo. With a ramp up in production on the horizon, ElectriCo had contacted several local colleges in 2015 to ask what programs they offered for basic microelectronics assembly and inspection. The community college, while offering nothing of the sort, seized on the opportunity to design such a program from scratch. A mechanical engineering faculty member was recruited to be the original instructor, and ElectriCo donated over a quarter million dollars in equipment and materials. Other microelectronics companies, including some of ElectriCo's suppliers, sat on the advisory board for the boot camp, but the curriculum was initially developed mainly by ElectriCo managers alongside the community college instructor. The first cohort of the boot camp was only four students, but consecutive cohorts soon grew to twelve, then sixteen students apiece, many of which were hired by ElectriCo.

To summarize, Haley's experience shows that workforce training for very specific skills can take place outside of the workplace:

- Mastering manufacturing work involving fine-motor skills takes repeated practice over time, so workers may not be able to work on "live" product while in training.
- Community colleges can successfully develop short-term training courses that meet employer needs, but attention needs to be paid to the sustainability of such programs across changing economic conditions.
- Community college training programs need to be designed to benefit the students, the firms, and the college.

Streamlining and organizing internal training: The ties between the boot camp and ElectriCo grew even stronger over the next few years. Several graduates of the program returned to the college as lab assistants. Some were ElectriCo employees

working weekend shifts who wanted extra income during the week. Two graduates of the boot camp also became full-time trainers at ElectriCo. One worked as a bonder—an assembler responsible for placing bonds made of gold wire on microelectronic modules—for nearly a year before taking on the training role. The other, a young woman named Emma, was hired on from a later boot camp cohort directly into the training role. A director at ElectriCo explained that this occurred during the peak of ElectriCo's hiring needs:

> [We need another trainer, but] I can't take someone off the floor from [the factory managers] because it would hurt [them] too much. [We figured we could] find someone in the pipeline who is extremely capable. And Emma had certain attributes that I felt [would make her] successful going right into that role.

This director was referring to Emma's prior experience in retail management and her clear skill at relating to people. Emma described how she helped the other trainer revamp the program from the bottom up:

> [Before, training] wasn't organized. [The other trainer] was the only one in there with this aggressive influx of people coming through. There was no time to breathe. I said, ok Emma, what would you do if you were starting doing this in retail? There was lots of stuff laying around. I took the first two months, and all I did was clean . . . Part of cleaning was finding out the right people to talk to . . . And I started building contacts; this is the person for this, this is the person for this, this is the person for this. Once things were clean, I could focus more on, when we train people, these are the things we need to do. Create a lesson plan.

Emma and the other trainer did much more than streamline and organize the internal training curriculum at ElectriCo. Before, trainees simply worked on scrap materials, laying epoxy slugs on glass plates—practicing certain skills and operating certain equipment only once or twice before being assigned to their regular shift in a factory. After the reorganization, trainees practiced their skills on a realistic mock product module, the metal housing for which was actually built in the machine shop at the community college. Trainees also tracked their progress in a mock version of the manufacturing software used in the factories. After completing skills practice and taking multiple choice assessments about manufacturing policies and processes, trainees engaged in several days of "soak time", which meant time spent shadowing and working with a mentor on the factory floor. Trainees then returned to the training room to assess their soak time experience and practice any last skills that required attention. Finally, trainees were released to the factory floor on their regular shifts. Despite these changes and extensions to the training experience, most trainees finished this entire process in less time than they had before the redesign. Graduates from the community college boot camp, as well as other new hires with no prior experience, completed this entire internal training process, though boot camp graduates often did so in half the time.

After several years, Emma and the training team were recognized for their efforts through a significant company award from headquarters, through a local news segment, and by visitors to the factory, who were always taken to the training room to learn about the program. As hiring slowed, the trainers filled their schedules by spending more time on the factory floor,

assisting with work and keeping updated with the ways that processes had changed. Incumbent workers were also brought into the training room for cross-training.

Though ElectriCo's hiring surge coincided with its renovations of several factories, including significant investment in automated bonding machines, optical inspectors, and epoxy-dispensing 'pick and place' machines, training on this automated equipment was not heavily emphasized in the curriculum of the community college boot camp or in the internal training program. For one thing, the company and the college did not have the funds to provide additional automated equipment for the training room or the college. For another, they viewed the manual skills as an essential foundation for any job, including one that intersected with automation. An upper-level manager explained the company's philosophy to the boot camp students as they took a tour of the ElectriCo factories:

> We keep saying automation, automation, so why are we teaching you the manual process? . . . Sometimes [machines] break, but [more importantly], if you don't know the techniques, what it should look like manually, how are you going to know what it's supposed to look like coming off of automation?

Another director added:

> And we're not all automated. Seventy [components] need to be placed manually [on the module] . . . . I don't have a vision for a 100% automated factory. I think there will be islands of automation, supplemented by people. Both have something to bring to the table. Like the automated inspector, [it] can tell if there's a bad bond present, but it can't always tell you if it's down [or just mis-oriented]. You need people to tell you that . . . And if I'm [working at a station] downstream from automation, seeing what automation does will make you better, because you know what it's supposed to do.

This director later described how ElectriCo thinks about assigning new hires to the tasks in the factory that required interfacing with automated equipment:

> We can't simulate [automation in the boot camp]. So that's all foreign [to new hires]. And we tried to look at personality traits [like] how fearless are they? Are they intimidated by computers and software, and x, y, z coordinates? If we think that they have those traits and they know what good [product] looks like, then we'll train them on [the automation].

While managers were satisfied with their method for incorporating automation into training , the pace of the hiring wave created a challenge, even for the new and improved training program. Some personnel needs were met by reassigning workers from other factories to those factories that were experiencing increased demand. The incumbent workers who had been reassigned spent time in the training room before embarking on their new assignments, and their experiences revealed challenges around management, communication, and technology on the factory floor, as we will see next.

To summarize, internal training is also necessary, and it can be done poorly or well:

- Emma was empowered to develop an internal training program using broad discretion. She needed time and freedom to learn how to accomplish change in the workplace, including gaining buy-in from managers and other administrators.
- Training takes place in several stages, transitioning from trainees practicing individual skills on mock products and software to performing multiple complex operations on real products with decreasing levels of supervision.
- Automation can be challenging to incorporate into training, but workers need foundational manual skills and knowledge before working with automation.

Challenges for incumbent work training around technology

Training for automation. Sharon Smith emerged from the training room at ElectriCo, which was adjacent to one of the factories. She had been deeply immersed in her microscope, practicing the skill of manually attaching electrical components to a glass plate with epoxy. But today, the trainers had scheduled some time for her to work on the automated optical inspector (AOI). Since the training room did not have an AOI (or any of the other automated machines that dotted the factory floor), Sharon would have to train using live product under the supervision of an inspector. This was her second training session on the AOI, and she had taken already detailed notes of the computer commands required to bring up the proper inspection program on the computer, to feed the product module into the AOI, to focus the camera, and to sift through the resulting images. Sharon was in her fifties, and she had worked for almost a decade at ElectriCo, but she was now transitioning into a factory that had more advanced equipment. This transition came with the opportunity to learn a whole suite of new tasks, including those that required basic computer use.

A halting reliance on notes. After checking in with Jake, the inspector that would be supervising her this afternoon, Sharon sat in front of the monitor attached to the AOI and looked at her notes. They told her that the first step was to load the module into a slot on the AOI. Sharon did so, and then looked at her notes again, for the next required step. Jake wandered over, and Sharon said, “I think the next step is to align [the camera]”. Jake, who was much younger than Sharon but quite fond of her, teasingly asked, “How are you going to align to something that's not there?” Sharon said, “I fed it,” and pointed to the module in the AOI slot. Jake slid the module in a bit further until it was recognized by the computer. He showed Sharon that there was a laser by the slot, and she had to line the module up flush with the end of the machine or the laser wouldn't recognize that it was there. Sharon said, “Okay,” but she was busy looking for the next step, which was to focus the camera. Jake reminded her that she hadn’t yet aligned the camera. She did this, and then Jake said, 'We're out of focus, so what now?” Sharon pointed to a button on the screen, “This thing, right?” Jake said, “Yep, you see the arrows that bring it into focus? So then right click anywhere

and select 'Zero Focus Position.'" Sharon didn't have this step on her notes from earlier, so she added it. Jake continued, "Yep, so start inspection. Make sure 'Save All Images" is checked, and press start." Finally, the AOI took over and automatically moved the camera over the surface of the module, taking pictures and assessing whether each component was in its proper place and orientation. After it was done, Sharon was required to review all of the pictures that contained errors that the machine had detected. But, Sharon accidentally clicked through the menu options, skipping the option to do a manual review. She called over to Jake, asking whether she needed to run the inspection again. He said, "Yes, but you can just do the last few steps." Sharon paused and said, "Too late." She had already gone back to the beginning of the process in her notes, and started to align the camera again.

To summarize, training certain workers to operate automated equipment, particularly some older workers, can be challenging:

- Automated equipment in microelectronics is relatively straightforward to operate, requiring a series of predictable, repeated computer clicks.
- Learning the computer interface and operations can be unexpectedly challenging for workers like Sharon who were not accustomed to using computers very intensively outside of the workplace or in their prior work.

Cultural and managerial challenges for on-the-job training: ElectriCo cross-trained or re-trained many incumbent workers during the several years surrounding the hiring wave. Another woman about Sharon's age, Anita, was also re-training after being out on the factory floor for nearly a year. While Anita had been at ElectriCo for almost a year, she had only performed one task in the factory during that time—one that required her to be in front of a microscope in a position that was straining for her neck, back, and arms. This wasn't the typical experience of new workers; Anita said that there was another woman in the factory who had several years' experience and was supposed to train and rotate new workers on a variety of skills so they were not stuck doing one task for months. Anita said, "She didn't want to, because she didn't want to move around [and spend time doing the less desirable tasks herself]."

Ordinarily, this may not have been a problem, since workers coming in after Anita would start out on that task and bump Anita up to a new position. However, there was a "perfect storm" of problems for Anita that meant she was stuck doing the worst task for months. Since hiring was slowing, Anita had not had a newer worker coming in behind her to take her place. So, her transition back into the training room came as a relief. This training was meant to refresh her other skills and allow her to perform other tasks in the factory.

After receiving "soak time" and a few final days in the training room, trainees like Anita were released to their shifts, but they still spent many weeks learning through informal on-the-job (OTJ) training with their co-workers and supervisors. In some work cells, like Anita's old one, this OTJ did not proceed as planned, with Anita rotating through different tasks. But, after

completing formal training, Anita was moved to one of the most established factories with many competent operators working on the bonding operations. Even these factories had some issues with the pressure created by the influx of new operators. Particularly on night and weekend shifts, new hires had little support from managers and little assistance from process engineers. One operator on first shift described to Anita how the automated bonding machines were often broken by operators on weekend shifts due to this lack of support and training:

> It's frustrating for a lot of us on first [shift]. Whatever [weekend shifts] don't get accomplished, that's thrown on our shoulders to get accomplished. I work ten hours and get twelve units done. In twelve hours, they're doing three [units] . . . I was on fourth shift for over three months, helping out with training, and I was blown away by what I was seeing . . . Because it's the weekend, stuff happens . . . That machine has been down since Saturday. They had to call [the vendor] to fix it . . . [Weekend workers break machines] on a regular basis. No idea [what happened]. The only thing I can think of, if they lost a wire [from the hook] or whatever [and ignored the warnings and performed the bond anyway], they [would have] crashed [the tool] into a unit . . . They're preoccupied doing things they shouldn't be. They're on YouTube, not paying attention . . . I've seen people downloading Netflix, downloading Hulu . . . When I train, I tell them that's a fireable offense. And they can choose to do it, but at least I know I told them.

In addition to the problems caused for the company by such rapid onboarding, the hiring wave also caused some precarity for workers. The vast majority of new hires, both from the boot camp and "off the street", were hired as contractors, without a benefits package. An ElectriCo director justified this practice as providing an extended trial period to socialize and evaluate new hires:

> We need that flexibility to make sure that we're- you know, we're not doing anyone any favors if we find out that it's not going to work out and then we have to go through this lengthy [termination] process. And it's painful for the person too, if they're an employee versus a contractor . . . We tell them that we start reviewing them after 90 days [for a transition to direct hire], but it's a very informal [process]. We had a person that would take a look at the entire contract list and, every month, . . . say to our supervisors, here are the people, who do you want to convert [to direct hires]? . . . Now we've got such a small list that we're doing it by exception. [Supervisors,] tell us when your people are ready and believe me, those people are talking to [their supervisors] after 90 days saying, what do you think? What do I have to work on? We've got some people that stay contractors for a while because they've got just a couple things to make sure [of] before we convert them, but we're rooting for them. We want people to be successful because then we're successful.

To summarize, cultural and managerial challenges around training can be exacerbated during times of change, like ElectriCo's hiring wave:

- Anita had a poor on-the-job training experience in her first position. One incumbent worker was allowed to hoard desirable tasks and leave Anita and other new hires stuck doing less desirable tasks, which created ergonomic issues and stilted learning.
- Even in well-run factories, night and weekend shifts receive less support, and this has tremendous implications across shifts. When off-shift workers break equipment or product, experienced first shift workers need to compensate by increasing their pace of work.

- Practices like using contract workers can create precarious working conditions, even as they are justified by management.

ElectriCo Summary: The box below summarizes the ElectriCo employees we've met and some of the training challenges each has faced. It also repeats the broader lessons we can draw from each topic.

Topic	*Workers and Managers*	*Lessons from their Stories*
Workforce training at the college	Haley: Twenty-year old single mom, student in the microelectronics community college boot camp. Has an aunt working at ElectriCo and wants to work there too to provide a better life for her and her son. Performing well but beginning to learn how long it takes to master all of the fine-motor skills required to be an assembler or inspector.	• Mastering manufacturing work involving fine-motor skills takes repeated practice over time, so workers may not be able to work on "live" product while in training. • Community colleges can successfully develop short-term training courses that meet employer needs, but attention needs to be paid to the sustainability of such programs across changing economic conditions. • Community college training programs need to be designed to benefit the students, the firms, and the college.
Streamlining and organizing internal training	Emma: Graduate of the community college boot camp with prior experience in retail management. Tapped to lead the development of an internal training program at ElectriCo and made significant changes that were later recognized by ElectriCo headquarters.	• Emma was empowered to develop an internal training program using broad discretion. She needed time and freedom to learn how to accomplish change in the workplace, including gaining buy-in from managers and other administrators. • Training takes place in several stages, transitioning from trainees practicing individual skills on mock products and software to performing multiple complex operations on real products with decreasing levels of supervision. • Automation can be challenging to incorporate into training, but workers need foundational manual skills and knowledge before working with automation.
Challenges for incumbent work training around technology	Sharon: Mid-fifties incumbent worker transitioning from one factory to another. Cross-training on multiple operations before moving factories and facing some challenges in picking up computer skills required for working with automated equipment.	• Automated equipment in microelectronics is relatively straightforward to operate, requiring a series of predictable, repeated computer clicks. • Learning the computer interface and operations can be unexpectedly challenging for workers like Sharon who were not accustomed to using computers very intensively outside of the workplace or in their prior work.

Cultural and managerial challenges for on-the-job training	Anita: Mid-fifties incumbent worker with one year of experience at ElectriCo. First factory was poorly run, leaving her stuck with an undesirable task for months and resulting back problems. Second factory was better but had issues with off-shift workers meaning that first shift workers like Anita needed to work even more intensively.	• Anita had a poor on-the-job training experience in her first position. One incumbent worker was allowed to hoard desirable tasks and leave Anita and other new hires stuck doing less desirable tasks, which created ergonomic issues and stilted learning. • Even in well-run factories, night and weekend shifts receive less support, and this has tremendous implications across shifts. When off-shift workers break equipment or product, experienced first shift workers need to compensate by increasing their pace of work. • Practices like using contract workers can create precarious working conditions, even as they are justified by management.

PART 3: INFLUENCES ON THE DESIGN OF EMPLOYER-PROVIDED TRAINING

The stories of MetalWorks and ElectriCo can illuminate some of the factors that influence the design and approach of employer-provided training in manufacturing. While the numerous differences between the two companies provide few controls and limit the conclusiveness of the evidence, we can use these cases to build hypotheses of the effects that occupational and organizational structures have on the nature of employer-provided training. This provides some broader lessons for other companies thinking about their own training practices. The box below summarizes these factors and the ways they might affect how employer-provided training takes place.

Organizational and Occupational Influences on Employer-Provided Training

	Characteristics	*Impact on training*
What are the similarities between the two firms at the organizational level?	"High road" employers Deploying front-line workers as a key competitive advantage and paying above market wages	"High road" employers are more likely to prioritize training and professional development and devote resources to these efforts
	Educational partnerships Developing relationships with high schools and colleges, including by providing co-op and internship experiences for students	Educational partnerships allow employers to outsource some training, especially basic skills training, and can create hiring pipelines

	Shift work Scheduling work across nights and weekends, in addition to day shifts	Organizing work across multiple shifts creates challenges for training incumbent workers in particular, since off-shift workers may have less supervision, less interaction with more skilled employees, and simpler work
What are the differences between the two firms at the organizational level?	Size and ownership MetalWorks: small, family-owned shop ElectriCo: large multi-national firm	Larger and more well-resourced firms may be able to develop more formal training programs and rely on a consistent influx of new workers to achieve a return on investment in training resources
	Business model and product mix MetalWorks: contract manufacturer; complex product mix ElectriCo: defense contractor; more stable product mix	Firms with complex product mixes and buyers across multiple industries may have increased challenges in formalizing a training program, particularly in evaluating worker competencies
What are the similarities between the occupations at the two firms?	Relative skill level Low educational barriers to entry but opportunity for wage progression and advancement without changing occupations	Occupations with low barriers to entry but opportunity for advancement require continual and intensive on-the-job training
	Labor pool challenges Employers report challenges of finding workers who can pass drug tests and come to work on time	Occupations that draw a challenging supply of labor can distract employers from the importance of codifying competencies and providing training for workers that do meet basic requirements
What are the differences between the occupations at the two firms?	Importance of knowledge vs. skill Machinists: mix of knowledge and skill; slight emphasis on knowledge Microelectronics: heavy emphasis on skill	It can be difficult to evaluate the competencies of workers in occupations that require a high degree of contextual knowledge, and occupations that require considerable physical skills can have long training periods
	Time to proficiency and time to mastery Machinists: rapid time to proficiency, slow time to mastery Microelectronics: slow time to proficiency, relatively rapid time to mastery	Occupations' time to proficiency affects whether workers can be trained on-the-job and how quickly they can be integrated into regular operations, while occupations' time to mastery affects the ease of codifying job tasks and skills
	Occupational meaning	

	Machinists: viewed as multi-generational lifelong career	Microelectronics: viewed as opportunity to build a career; discovered by happenstance	Occupational meaning affects the motivations workers bring to their jobs and should be considered when developing training; in particular, training should demonstrate to workers how improving one's skills aligns with these motivations

ORGANIZATIONAL LEVEL

Organizational similarities: MetalWorks and ElectriCo are similar in several key ways that affect their workforce training. First, both companies are examples of "high road" employers – those that attempt to compete not on the basis of lowering the cost of labor but instead by deploying their front-line workers as a key competitive advantage. The language of upper management in both firms reinforces this commitment, with MetalWorks professing that "people is our number one asset", and ElectriCo echoing this by praising top management's approach of "embracing the diversity of the people and [viewing] them as our most precious resource". Similarly, both companies state a desire to be an "employer of choice" in the community. Even if the training programs need improvement to serve all types of workers effectively, valuing the contributions of front-line workers is a fundamental practice in these companies. It results in the prioritization of the training and professional development of workers, and the devotion of resources toward these goals.

Second, both MetalWorks and ElectriCo built partnerships with educational institutions in their communities, and they leverage these partnerships to provide at least some portion of the necessary training for workers. MetalWorks partners with both vocational high schools and college-level engineering programs, taking on between five and ten co-op students per year. In an organization with fewer than fifty production workers, training and managing these co-ops is not insignificant. Yet many of MetalWorks' incumbent employees graduated from programs at these partnering institutions, and, as we saw with Damien and Tara, have used their alumni status to recruit additional co-ops and full-time employees to the firm. The partnering schools provide foundational industry knowledge and occupational skills, including in machining, blueprint reading, and the use of inspection equipment, to MetalWorks workers. At ElectriCo, we saw a more intensive partnership through the community college microelectronics boot camp. Because ElectriCo is a larger employer, it had both the need for a larger pool of workers and the resources to support this program. The program provides qualified and vetted workers to ElectriCo, meaning that the company's internal training program emphasized company-specific workflow and policies, as well as equipment operation, rather than foundational manual skills, which were taught at the college. The boot camp also benefits the company in non-obvious ways. It produced two graduates who themselves had a knack for training and curriculum design, it improves ElectriCo's reputation through the media coverage of the graduates' successes, and it delivers additional talent to ElectriCo's local

suppliers and industry partners. It should be noted that ElectriCo's partnership, in particular, follows the trend of the private sector outsourcing training costs to the public sector, and that this may produce undesirable results for the boot camp students and the college, if ElectriCo withdraws support and if the graduates are not able to find well-paying jobs at other firms. ElectriCo is also beginning additional, more symbiotic, partnerships, one with a local vocational high school, from which it has taken on two summer interns, and the other with the American Society of Mechanical Engineers group at a local university campus, with which it occasionally collaborates on experimental 3-D metal printing projects.

Third, MetalWorks and ElectriCo operate under shift work – MetalWorks with a first and second shift, and ElectriCo with three eight-hour weekday shifts and two twelve-hour weekend shifts. In contrast to the first two similarities described above, shift work provides a challenge for training, rather than an advantage. In both companies, workers on off-shifts (nights and weekends) are provided fewer opportunities for training. While MetalWorks considers this an unavoidable and acceptable outcome, at least for the time being, ElectriCo has found this to be problematic. ElectriCo's off-shifts had been filled rapidly due to increased demand for production, and a significant portion of off-shift workers were hired in a two-year timeframe. Despite the need for increased production, ElectriCo has not seen fully mature production rates from the off-shifts, and a tendency of off-shift workers to break equipment has occasionally reduced production rates on first shift as well. This dynamic does not stem from differences in the initial training experiences of these off-shift workers, who were hired through similar sources and were exposed to the same initial formal training program as first shift workers, nor from differences in inherent skill or motivation, since off-shift workers were either assigned to these shifts based on availability, not skill level, or chose them due to home or family needs. Instead, it is important to recognize that training does not end when a worker demonstrates a list of competencies and leaves the training room. Instead, on-the-job training continues once the worker arrives on the factory floor through repeated informal interactions—including questions, critiques, and directives—from managers, engineers, and co-workers. New workers on off-shifts have less support from each of these groups, and their on-the-job training suffers accordingly.

Organizational differences: MetalWorks and ElectriCo are also different in several key ways that affect their workforce training. First, MetalWorks is a small, family-owned company of fewer than one hundred employees, while ElectriCo is a multi-national firm that is among the largest defense contractors in the world. (Only one U.S. establishment of ElectriCo is profiled in this case study, but this location alone houses several thousand employees.) This difference in size creates a differing ability of these firms to devote resources to training. ElectriCo, which did have a chaotic and ineffective training model in the years leading up to their hiring wave, was able to invest considerable resources to improving training and could benefit from a return on that investment over the next several years. During this time, ElectriCo had a continual supply of new workers that needed training, so these training resources were not sitting

idle. MetalWorks, on the other hand, consistently struggled to devote time and personnel resources to training, since they viewed these resources as better spent on urgent production issues. In contrast to ElectriCo's consistent influx of new workers, new workers entered MetalWorks by ones and twos at inconsistent times, so they were each trained individually and received quite different experiences depending on a host of factors.

Second, MetalWorks and ElectriCo operate under different business models—MetalWorks as a contract manufacturer making thousands of different parts each year for different industries and customers, and ElectriCo as a defense contractor producing different variations and designs of a consistent set of products for a limited number of customers. The variety in product mix and "job shop" environment created challenges for MetalWorks' training efforts. New workers were frequently assigned to run repeat jobs that had proven processes, but they were rotated to different jobs at different rates based on the workers' interest and operational needs. It was particularly difficult to track the competencies of incumbent workers, and much of the knowledge about worker abilities, interests, and tendencies remained in the heads of shop floor supervisors, rather than in a written document. At ElectriCo, on the other hand, the product mix was less variable, and each product required very similar operations, making it easier to track both new and incumbent worker competencies. ElectriCo designed a system whereby workers were certified on these competencies and could be rotated through the training room for cross-training when there was available time and space. However, this created a tendency for managers to view training as sufficient when competencies were checked off on paper rather than when workers truly felt competent and could perform at high levels.

OCCUPATIONAL LEVEL

Occupational similarities: While MetalWorks and ElectriCo each employed workers in a variety of occupations, the majority of front-line workers at MetalWorks are machinists, and the majority of front-line workers in the focal factories at ElectriCo are microelectronics assemblers. These two occupations are similar in several key ways that affect how workforce training is delivered. First, they are similar in skill level relative to other occupations. Both machining and microelectronics assembly positions are available to entry-level workers and have relatively low educational requirements. (They should not, however, be considered only as low-skill occupations, since both provide considerable opportunities for wage progression and advancement as workers become more experienced and skilled.) As with many manufacturing occupations, continual learning and skill development takes place over a long period of time, making on-the-job learning the primary form of training. Even when firms partner with education institutions for initial training, as MetalWorks and ElectriCo did, employers of these occupations should be prepared to continually invest in the development of their workers.

Second, because of the low educational barriers to entry, employers of these occupations draw from similar labor pools and face similar challenges in hiring and training. While MetalWorks and ElectriCo

managers did not do this, it is not uncommon to hear these types of employers complain that they will hire and train anyone that can pass a drug test and show up to work on time. However, employers should not be too quick to dismiss the difficulty in codifying the necessary worker competencies and developing effective training programs. As with the two companies profiled here, incumbent worker training is often particularly neglected, because incumbent workers have generally demonstrated necessary personal competencies including timeliness and the ability to get along with co-workers and supervisors. They might therefore be overlooked for further technical training.

Occupational differences: Machining and microelectronics assembly occupations also differ in several key ways that affect how workforce training is delivered. First, while both might be considered middle- to low-skill occupations, depending on the experience of the worker, the mix of knowledge versus skill required for proficiency differs between these two occupations. Machining at MetalWorks required a mix of knowledge and skill, with a slight emphasis on knowledge. Machinists are required to develop knowledge of how the machines worked, how to change the tools, what to look for when troubleshooting, and what inspection equipment was appropriate for measuring different types of parts. Skill is required in handling the parts, given that they are often held to tolerances of several thousandths of an inch. This means that evaluating worker competencies is a difficult aspect of training. Prior to hire, MetalWorks required interviewees to complete several multiple-choice tests that examined their knowledge of basic machining and quality control terminology. Much of the training process then required trainers to verbalize what they were thinking when troubleshooting or inspecting, including how they selected one particular method over another and what alternatives existed. In contrast, microelectronics assembly at ElectriCo requires a different mix of knowledge and skill, with a strong emphasis on skill. While assemblers are required to study dense pages of military specifications regarding acceptable work standards, an outsized portion of their training is spent practicing fine motor skills under a microscope. In the ten-week community college boot camp, roughly 75% of students' time was spent on hands-on practice, while the remainder was devoted to lectures on lean management, military specifications, and general terminology.

Second, and relatedly, the two occupations differ in their time to proficiency and time to mastery. New machinists at MetalWorks generally demonstrate a rapid time to achieve proficiency—as long as they had been exposed to some machining skills at school, they could often perform useful work after only a few hours of training at the company. However, they required a long time to achieve mastery. Managers at MetalWorks commented on the advanced abilities of experienced machinists to use sound and touch when troubleshooting issues with their machines. They acknowledged that these were abilities that were difficult to teach but were developed over time, often on the order of years. In contrast, at ElectriCo, new microelectronics assemblers require a long time to achieve proficiency—they were not allowed to touch active product for several weeks to several months during

training, and once they were placed on their regular shifts, every unit they built was closely inspected by a more experienced worker before being moved to the next operation. However, the assemblers exhibit a relatively rapid time to mastery, often becoming trainers or supervisors themselves within six months to a year.

Third, the two occupations differ in how most workers select and view them. Machining, at MetalWorks and elsewhere, is commonly a lifelong career and can often run through multiple generations of families. Workers entering as experienced hires at MetalWorks often worked as machinists at multiple companies over many years, and young workers often selected machining as their future occupation as early as grade nine (since many came from vocational schools that offered such programs). Because of this, machinists brought a particular set of motivations to their work. Many of them emphasized that they wanted to continually improve in their craft and desired to continue in machining for many years. Training at MetalWorks, therefore, emphasized craft-building and provided opportunities for workers to learn different types of machines and different types of parts. In contrast, microelectronics assemblers at ElectriCo often had eclectic work experiences and came to ElectriCo by happenstance rather than as an intentional career decision. Workers entering as experienced hires had careers ranging from medical assisting to hair styling. Managers at ElectriCo said that they looked positively on these experiences, since these workers often had advanced fine motor skills and a predilection to work with their hands. Inexperienced hires, including those who entered via the community college boot camp, often had limited work experience in retail or food service and wished to transition into a job where they had better prospects to build a career. While many entering workers applied to ElectriCo because a family member worked there, the occupation or industry did not run through multiple generations of their families, as it did with machining. Because of these dynamics, microelectronics assemblers brought a different set of motivations to their work. Training at ElectriCo, therefore, emphasized the company mission and values and the opportunity to receive good benefits and advance into administrative or engineering positions.

CONCLUSION

Part 1 of this case study featured MetalWorks, a small, family-owned machine tool shop that highly values its workers for the contributions they make to the company. Training for machine operators is largely informal, though MetalWorks partners with local high schools and colleges to benefit from the vocational education they provide. Managers at MetalWorks have struggled to formalize operator training and evaluation, not least because they feel they cannot pull experienced workers from their machines to train. There are a few key takeaways we can draw from MetalWorks' experience:

- While on-the-job training can be very informal and unstructured, it still requires a good deal of time from helpful, expert incumbent employees.

- Complex product mixes, suboptimal organization of work, and competing manager priorities all affect the viability of any formal training plan.
- Managers can tap certain incumbent workers to take on informal training responsibilities, and repeated experiences helps these workers learn to train more effectively. However, these workers still provide a variable experience for new hires, because they may relay incomplete or inconsistent information.
- An informal training environment where incumbent workers provide the training makes it difficult for all workers, especially the less-supported night shift, to get the training they will need on advanced technologies, such as robotics, that are entering the workplace

Part 2 of this case study featured ElectriCo, a multinational defense contractor making microelectronic products and systems. The focal establishment has an elaborate formal training program newly designed by several front-line workers. One of these workers is a graduate of a community college boot camp program that ElectriCo sponsored to provide an initial ten weeks of training to potential new employees. Still, on-the-job training at ElectriCo is fraught with challenges around technology, culture, and managerial support. There are a few key takeaways we can draw from MetalWorks' experience:

- Community colleges can successfully develop short-term training courses that meet employer needs, but attention needs to be paid to the sustainability of such programs across changing economic conditions and the extent to which they meet the needs of students and the college.
- Training—even within the company—takes place in several stages, transitioning from trainees practicing individual skills on mock products and software to performing multiple complex operations on real products with decreasing levels of supervision.
- Automation can be challenging to incorporate into training and may be unexpectedly challenging for workers who don't have prior computer skills.
- Even in well-run factories, night and weekend shifts receive less support, and this has tremendous implications across shifts. When off-shift workers break equipment or product, experienced first shift workers need to compensate by increasing their pace of work

Part 3 of this case compared MetalWorks and ElectriCo, aiming to draw lessons about the organizational characteristics of these organizations and the occupational characteristics of the main positions in these companies. These organizational and occupational factors have implications for how employer-provided training is designed and maintained. Managers should consider straightforward organizational factors such as size, ownership, and business model, but also whether the company has the ability to partner with local educational institutions, how employees are empowered to provide value to the firm, and whether work is organized across multiple shifts.

Managers should also consider the occupations for which they are designing training, including the following:

- The relative skill mix – whether the occupation is generally low, medium or high skilled, which affects how much ongoing training and development workers will need and what career paths should be developed as part of the training program
- The importance of knowledge vs. skills to the occupation – which has implications for how content should be delivered and how long the training period is likely to last
- Time to proficiency and time to mastery – which affects where training can take place, whether trainees can contribute to valuable work on real product, and how long the training period is likely to last
- The characteristics of the labor pool – what challenges exist in the likely pool of workers and how the organization can help address them rather than blaming the individuals
- Occupational meaning – how workers typically come to the occupation and what meaning it might hold for them as related to their families and their long-term career lives, which can provide insight into how trainers and companies can motivate trainees

While this case study has provided a deep window into employer-provided training at MetalWorks and ElectriCo, it is important to note the variation that exists within the manufacturing sector and across industries. In particular, different industries have different regulatory environments and respond differently to economic and technological developments. These factors deeply affect how employer-provided training can and should be designed to benefit both employers and workers.

It is also necessary to say an additional word about how technology and training intersect. While the above narratives feature workers who are being trained in advanced manufacturing at successful companies, it is somewhat unexpected—given the dominant rhetoric in both academic and practitioner circles—that automation is merely a supporting character in the narratives, and artificial intelligence is entirely absent. MetalWorks has invested in robotic machinery and industrial internet-of-things (IIOT) software, and its machinists operate equipment that is relatively advanced for a small company. While several machinists have been trained to supervise the robotic machinery, all of them work on machines that have only incrementally changed over the past several decades. Some machinists are concerned for their children who want to enter the industry, but they know that their jobs will continue to be relevant and challenging overall. Meanwhile, ElectriCo assemblers and inspectors perform manual tasks next to automated equipment that performs very similar work. Despite the outward appearance that they are performing tasks that are substitutable by technology, these workers are generally unconcerned. Their factory floors are far from being fully automated, and the workers can see the inconsistency of the machines and their inability to handle the more complex products. They know that the company's emphasis on manual skills during training is somewhat due to restrictions in including automation in the training process but is mostly due to the company's continued

insistence on the importance of manual proficiency. On the one hand, minor role that technology played in these cases should raise concerns that neither employers nor workers are prepared for a more automated world and that significant investments in training (and in learning how to train) will be necessary. On the other hand, it demonstrates that employer-provided training is difficult and necessary, regardless of the future trajectory of new technologies.

---

[i] https://www.npr.org/2019/07/11/740660070/from-the-warehouse-to-it-amazon-offering-100-000-workers-tech-training

[ii] Organization names are pseudonyms, and all individual names have been changed